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ADC019153	
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GULF OF MEXICO AND CARIBBEAN SEA DATA AND MODEL BASE REPORT (U)

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(14) TRHCOR- E-79-RV-513C
(15) N00014-78C-0186
(11) LRAPP REPORT-C79-027

(12) NOTLF

(12) 220

(6) GULF OF MEXICO AND CARIBBEAN SEA

DATA AND MODEL BASE REPORT (U)

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JULY 1979

LONG RANGE ACOUSTIC PROPAGATION PROJECT

NAVAL OCEAN RESEARCH AND DEVELOPMENT ACTIVITY
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FOREWORD

The Long Range Acoustic Propagation Project (LRAPP) of the Naval Ocean Research and Development Activity (NORDA) has sponsored a series of intensive measurement exercises in various ocean areas. In addition, LRAPP has sponsored an extensive program of acoustic model development and evaluation, used for analysis and systems development applications as well as fleet operational performance prediction. The Assessment Program applies the results of these measurement and modeling efforts to prediction of generic systems performance by ocean basin. Pre-assessments, of which the Gulf of Mexico/Caribbean Pre-assessment is an example, provide a "prediction" or hypothesis of expected system performance prior to a major LRAPP exercise series. This prediction is based on a survey of available environmental and acoustic data, plus basic acoustic modeling and systems performance prediction. The Pre-assessment provides an opportunity to determine how well ocean acoustics and system performance can be predicted in advance or in absence of a dedicated measurements program. Further, the Pre-assess- ment is designed to highlight deficiencies in model prediction capability and demonstrate the sensitivity of model results to key environmental data.

The Gulf of Mexico/Caribbean Pre-assessment was carried out during the CHURCH STROKE III exercise planning process and interaction with the exercise principal investigators provided a unique opportunity to:

- Identify critical environmental data requirements;
- Identify acoustic characteristics unique to the exercise area;
- Identify special modeling requirements; and
- Establish the key technical issues for the planned experiments.

With emphasis on the CHURCH STROKE III measurements, attention was restricted to the sensors to be deployed in the experiment, and prediction of the signal and noise fields as expected during the measurement exercises.

This volume, the first of three reports which comprise the Gulf of Mexico/Caribbean Sea Pre-assessment, documents the existing data base available for upcoming CHURCH STROKE III measurement areas including:

- Physical environmental data;
- Acoustic data; and
- Models available.

The second report will provide the model prediction of propagation loss and noise at the measurement system locations. The third report will provide an interpretation of these results, and a preliminary analysis of the expected performance of certain generic surveillance systems.

K. E. Evans, Manager
LRAPP Modeling Program

(U) ACKNOWLEDGEMENTS (U)

(U) This Regional Pre-Assessment is the product of the combined efforts of a substantial number of scientists and engineers with extensive experience in underwater acoustics and surveillance. The editor wishes especially to acknowledge the following:

- Dr. R. Gaul, Director of the Long Range Acoustic Propagation Project (LRAPP); LCDR K. Evans, the cognizant LRAPP Assessment Project Manager; V. Anderson, Undersea Research Corporation (URC), the Program Support Advisor, assisted by D. Hathway, also of URC; and Dr. M. Weinstein, Underwater Systems, Inc., the Technical Support Advisor, who were principally responsible for the structuring of the Pre-Assessment program.
- The planners of the CHURCH STROKE III Exercise, who interacted with the members of the Pre-Assessment Team to their mutual benefit, Dr. S. Daubin, Daubin Systems Corporation; J. Gottwald, Tracor; and Dr. A. Wittenborn, Tracor.
- Those who contributed directly to the content of this document, as Principal Investigators, author or both, B. Brunson and J. Davis, NORDA 320; G. Ellis and S. Mitchell, Applied Research Laboratories, University of Texas at Austin; R. Hecht and D. Young, Underwater Systems, Inc.; R. Kirklin, Tracor; Dr. L. Solomon and C. Lunsford, Planning Systems Inc.; and C. Spofford, Science Applications, Inc.
- Finally, O. Eiland, Tracor, who supervised the preparation of the final copy, its reproduction and distribution.

W. E. Wallace, Editor
Underwater Systems, Inc.

EXECUTIVE SUMMARY

The overall technical approach taken in this effort is the formation of hypotheses of system performance based on the best available data and models, which the CHURCH STROKE THREE measurement operations will then test, in the following steps:

- Help define, in concert with the exercise planning process, those environmental and acoustic parameters and processes that are of importance for the prediction of (measurement) systems performance in the Gulf of Mexico and Caribbean regions.

- Survey and evaluate the physical and acoustic data available for the Gulf of Mexico and Caribbean exercise regions.

- By use of available data and models, hypothesize the results expected from the planned measurement exercises, and in concert with the exercise planning process, identify those required measurements and data expected to be collected.

- Predict the measurement results expected in the exercise areas, both in terms of acoustic parameters ([illegible], [illegible], [illegible]) and measurement system performance (beam noise, S/N ratio, etc.).

- Finalize the critical measurements required to help confirm the models and strengthen the data base.

<u>Major Conclusions Reached to Date:</u>

<u>Adequacy of Data:</u>

1. <u>Environmental Data</u>

   - Bathymetry, sound velocity profiles and wind speed data are adequate for exercise planning purposes. Surface and

sub-surface current levels and magnitude are reasonably well understood; however, the effect on measurement system performance is not well understood and not easily predictable.

2. Bottom Loss Data.

- Bottom loss data are very limited and have been identified as an environmental input deficiency.
- Estimates of bottom loss have been prepared by two different scientific teams as presented in the body of this report. Because of the bottom-limited character of the Gulf of Mexico area, more data are needed.
- The location of shipping lanes over steeply sloping bottoms, and the location of oil industry activity in shallow water, make bottom information in these regions of considerable interest. The efficiency of downslope conversion depends strongly on this parameter.

3. Propagation Loss Data.

- In deep water there are no data from shallow sources to receivers at any depth for bottom-limited propagation, which is the dominant propagation mode in the Gulf of Mexico. Thus, the effect of bottom interaction is not demonstrable from experimental data.
- The experimental acoustic propagation loss data available for the Gulf of Mexico include shallow water sites in the eastern Gulf and deep source/receiver configurations in deep water.
- The best propagation loss data are for the Cayman Trench region of the Caribbean, obtained during the CHURCH GABBRO experiment. The steeply sloping walls of the Cayman Trench may have a significant impact on propagation.

4. Ambient Noise.

- There are no experimental noise data in the western Gulf of Mexico.
- There are limited amounts of data as a function of receiver depth in the eastern Gulf of Mexico.
- There are no horizontal directional noise data throughout the exercise area.
- There is only one set of vertical directionality data obtained in the Cayman Trench.
- Archival data for merchant and fishing vessels are adequate for identifying the major ambient noise features. As is usually the case, the dynamic variability makes it important to determine the shipping distribution at the time of the experiment to understand the observed noise directionality and for use as inputs to model predictions.
- The source levels and spectral characteristics of merchant ships, drill rigs, and seismic profiling sources are reasonably well known. Lacking better data, fishing vessels are assumed to be 10 dB quieter than merchant ships; production platforms are assumed to be similar to drill rigs, corrected for total power generation on board. These source levels have not been substantiated with measured data. Available data are adequate to estimate the scope of the problem presented by production platforms, mobile drill rigs, and seismic profilers.

5. Impact on Exercise Planning

Offshore oil industry activity is particularly heavy in the Gulf of Mexico. Because of the very high broadband levels generated by seismic profilers, it is anticipated that they will be a major source of noise interference in the western Gulf, and may couple into the eastern Gulf.

Oil production platforms, drill rigs and seismic profilers are predominately located west of New Orleans, where there are no shallow water data.

Since there are no noise data in the western Gulf, the potential for oil industry noise in that region cannot be further assessed prior to the performance of the CHURCH STROKE III exercise.

Individual drilling rigs may be a major source of line component noise depending upon how well their radiated signals are coupled into deeper water by downslope conversion. The several thousand production platforms are generally located in shallow water. The extent to which they will influence noise levels depends on the propagation loss from shallow water to the steeply sloping regions and subsequent conversion to channeled propagation in the deeper water regions. Because of the very large number of production platforms present, substantial propagation loss can be sustained and still permit significant noise contribution. If this occurs, it is anticipated that there will be a strong depth dependence of noise with maximum values in the vicinity of the deep sound channel axis, and perhaps little or no effect on near-surface or near-bottom sensors.

The noise data in the eastern Gulf do not indicate a significant increase in noise levels at the deep channel axis. However, the location of these sites relative to the shipping lanes indicates that the noise levels may be dominated by nearby shipping to an extent that would obscure such effects. Thus the potential of surface ships contributing significantly to the ambient noise over steeply sloping regions cannot be further assessed at this time.

6. Acoustic Modeling Predictions:

- Acoustic model predictions indicate that propagation from sources on the sloping coastal areas can be well coupled to the deep sound channel by downslope conversion if the bottom loss on the steep slopes is not too high. The experimental shallow water data in the eastern Gulf suggest that this may occur, but are not conclusive.

- Acoustic modeling capabilities appear to be adequate for prediction in the area with the following notable exceptions:

  (1) Three-dimensional models may be needed to understand propagation in the Cayman Trench and to predict cross-slope propagation in the steeply sloping bottom regions.

  (2) Downslope propagation loss models have to be capable of treating non-zero bottom loss conditions below critical grazing angles in the steeply sloping bottom regions.

<u>Summary</u>:

The major contributions of the pre-assessment study include:

- Identification of the need for bottom loss (bottom interaction) data and the geographical locations at which it is most important.

- Identification of the potential for noise interference from oil drilling and oil production activities in the western Gulf, as well as merchant shipping over steeply sloping regions of the eastern Gulf.

- Identification of the character of this noise interference in the spectral domain, and as a function of depth.

Specific experimental recommendations include:

- Measurement of noise as a function of depth in the western Gulf.

- Measurement of downslope propagation.

- Placement of the LAMBDA array in the western and eastern Gulf so as to minimize noise effects by employing topographical shielding.

- Investigation of coupling of noise between the Gulf and the Caribbean.

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1.0 (U) INTRODUCTION (U)

1.1 (U) Purpose (U)

(U) This document is one of a series of planned Pre-Assessments and Regional Assessments prepared under the management and technical direction of the Long Range Acoustic Propagation Project (LRAPP) of the Naval Ocean Research and Development Activity (NORDA). These documents are intended for use by those responsible for the application of surveillance resources, deployment planning and development decisions concerning ASW surveillance systems, and the design of such systems. The pre-assessment is the first step in achieving the initial objectives of a regional assessment program of data collection, analysis, modeling, and prediction, leading to the broader objectives of a regional assessment analysis.

(U) The Gulf of Mexico and Caribbean Sea is defined as that body of water bounded to the north, west, and south by North, Central and South America, and the east by the various islands commonly known as the Caribbean Island chain. The intent of this pre-assessment is to provide key Navy activities responsible for the design, development, test, procurement, deployment and operation of surveillance and other ASW systems an evaluation of:

- The quantity and quality of the available data describing the physical and acoustic properties of the area.
- The applicability, utility and accuracy of models to predict ocean acoustic properties in this region.
- The ability to estimate system performance within the region as a function of position and season.

In addition, this pre-assessment effort is keyed to the CHURCH STROKE III Exercise to be conducted by LRAPP. Specifically, the effort is intended:

- To provide a technical basis for planning the exercise.
- To identify any special characteristics of the exercise area that will control its acoustic properties and the performance of surveillance and other ASW systems.

(U)

- To predict, where possible, the acoustic parameters to be measured prior to the performance of the experiment, and to identify the technical difficulties attendant thereto.

Since the pre-assessment effort is keyed to the CHURCH STROKE III Exercise, emphasis has been placed on consideration of sensor emplacements in the Sigsbee Deep, the Straits of Florida, the Yucatan Channel, the Yucatan Basin, and the Cayman Trough. The southern portion of the Caribbean Sea is excluded, except to the extent that existing data might impact on ambient noise in the regions of concern.

1.2 (U) Organization of the Report (U)

(U) This report is presented as a series of papers with the author of each identified. References applicable to each chapter are given at the end of that chapter. Chapter 2, Environmental Data Summary, provides a description of the bathymetry, weather and climatology, ocean currents and fronts, sound speed structure, depth excess and critical depth, and bottom loss in the CHURCH STROKE III Exercise area and identifies the available data on each. It also includes pre-exercise estimates of bottom interaction. Chapter 3, Acoustic Data Summary, provides data on propagation loss, ambient noise, and industry activity and shipping distribution, and assesses the adequacy of the available data to describe the environment. Chapter 4 catalogs the model runs available for propagation loss and omnidirectional and directional ambient noise, and discusses the consistency of the model inputs with the environment for which used. Chapter 5 summarizes the pre-exercise model runs requested, and Chapter 6 summarizes the major conclusions.

2.0 (U) ENVIRONMENTAL DATA SUMMARY (U)

R. Kirklin

Tracor, Inc.

2.1 (U) Bathymetry (U)

2.1.1 (U) Description (U)

(U) The Caribbean Sea is bounded by the Antillean Chain to the north and east; South America to the south; and Central America, including the Yucatan Peninsula to the south and west. The upper 2000 meters of the Caribbean Sea have access to the water of the Atlantic Ocean through numerous passages through the Antilles. The total area of the Caribbean is 2,640,000 km^2 (Ewing & Edgar, 1966). The major basins of the Caribbean, with depths in parentheses, are: Grenada (>3000m), Venezuela (>5000m), Colombia (>4000m), Cayman (>6000m), and Yucatan (>5000m). The greatest depth is slightly over 7100 m in the Cayman Trench. The physiographic subdivisions of the Caribbean Sea and Gulf of Mexico are given in Figure 2-1. The bathymetry of the Gulf and northern Caribbean is shown in Figure 2-2.

(U) The Gulf of Mexico is a relatively shallow, oceanic type basin located at the southeastern boundary of North America. The total area of the Gulf of Mexico is approximately 1,602,000 km^2 (Harding & Nowlin, 1966). The greatest depth occurs in the Sigsbee Deep and is slightly less than 3750 meters.

2.1.2 (U) Availability of Detailed Charts (U)

(U) On a regional basis, the most accurate bathymetric charts of the Gulf of Mexico and Caribbean Sea that are available in the open literature are U.S. Geological Survey (USGS) Open File Maps 75-140 and 75-146, respectively (Busch, Rubin, 1978, personal communication). These charts use a contour interval of 200 meters. The classified charts from which the USGS charts were generated are available from NORDA (Code 340). Also available from NORDA are Bottom Contour (BC) charts. These are large

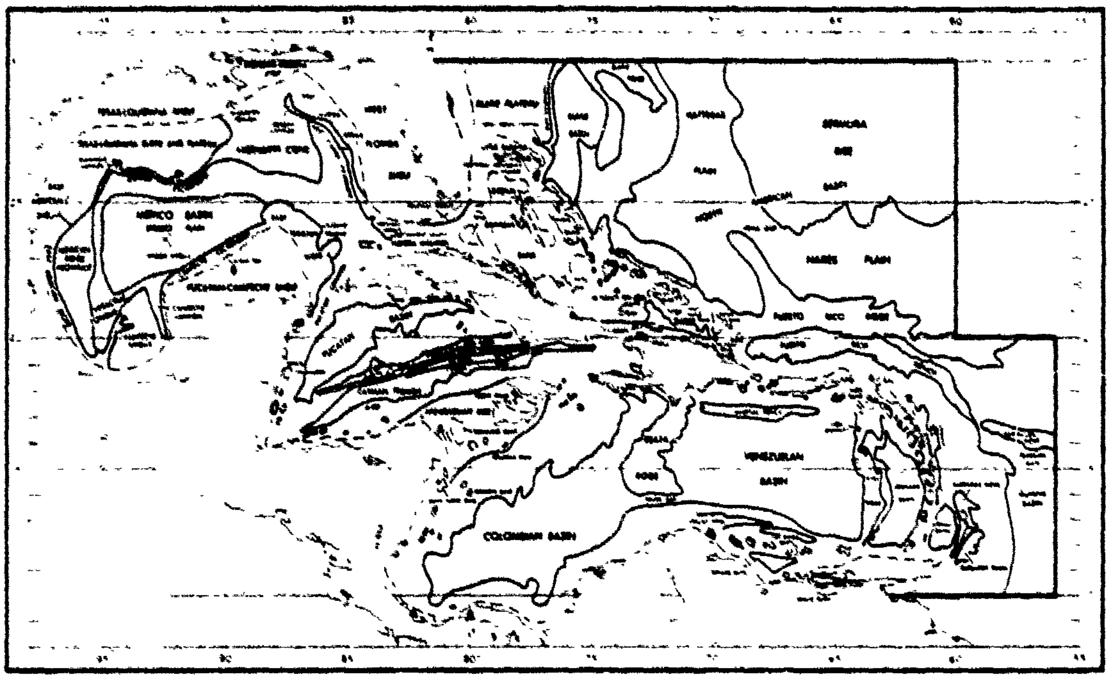


Figure 2-1. (U) Physiographic Subdivisions of the Gulf of Mexico and Caribbean Sea (U)

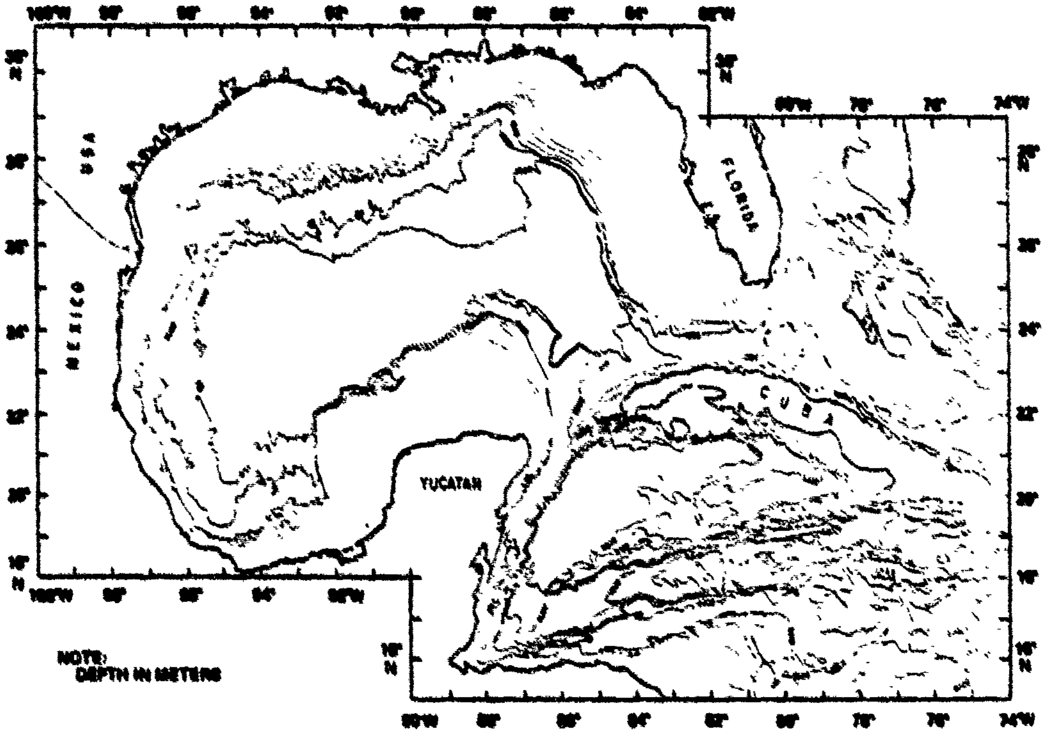


Figure 2-2. (U) Bathymetry of the Gulf of Mexico and Northern Caribbean Sea (U)

(U)

scale, detailed charts some of which are classified confidential. Approximately ten charts are required to cover the Gulf of Mexico and Caribbean Sea region.

(U) Charts of the continental shelf off the coast of the United States are available from the American Association of Petroleum Geologists. These charts use a contour interval of one fathom to a depth of 25 fathoms, then five fathoms to a depth of 100 fathoms, then an interval of 25 fathoms for depths greater than 100 fathoms.

(U) Detailed charts of the U.S. coastal regions may be purchased from the National Oceanic and Atmospheric Administration (NOAA). Figure 2-3 identifies the NOAA bathymetric charts that are available. Figure 2-4 illustrates the detail of these charts. Figure 2-4 is also an example of a small portion of NOAA chart NH 16-10(OCS). The NOAA charts use a contour interval of 2 meters to a depth of 200 meters, then an interval of 10 meters for depths greater than 200 meters.

(U) Available from the Defense Mapping Agency Hydrographic Center are ocean sounding plotting sheets of the General Bathymetric Chart of the Oceans (GEBCO) series. The GEBCO series consist of sounding data presented on Mercator projection plotting sheets at a scale of 1:1,000,000 at the Equator. GEBCO charts are available for the entire Gulf of Mexico and Caribbean Sea region through charts G0905, G1004, and G1005 in the Gulf and G0703, G0803, G0804, G0903 and G0904 in the Caribbean. All soundings on GEBCO presentations are in fathoms and are based on a nominal sound velocity of 800 fathoms per second. Depth corrections that take into account a variable sound speed profile with depth and which are based on National Oceanographic Data Center (NODC) sound speed summaries have been computed for five degree quadrants (Gold & Audet, 1973).

(U) In addition to bathymetric maps and charts, the Synthetic Bathymetric Profiling System (SYNBAPS) program can be used in the Gulf of

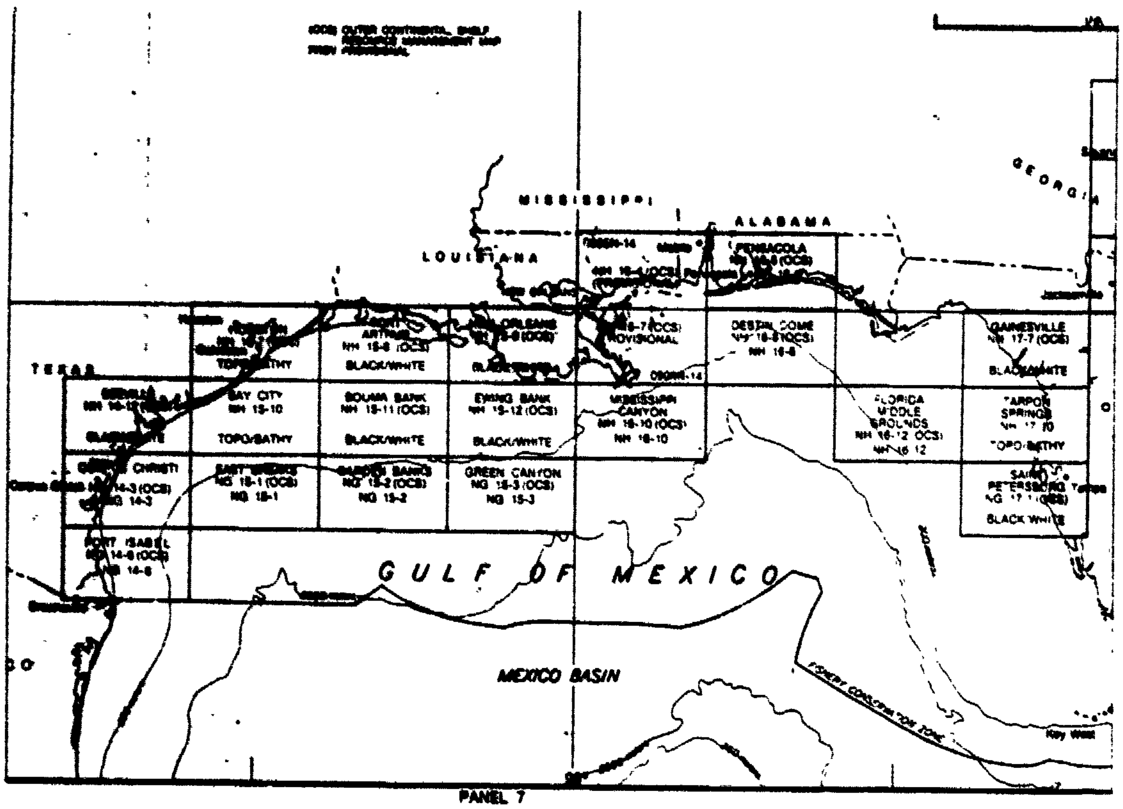


Figure 2-3. (U) Bathymetric Charts of the Gulf of Mexico Available from NOAA. (U)

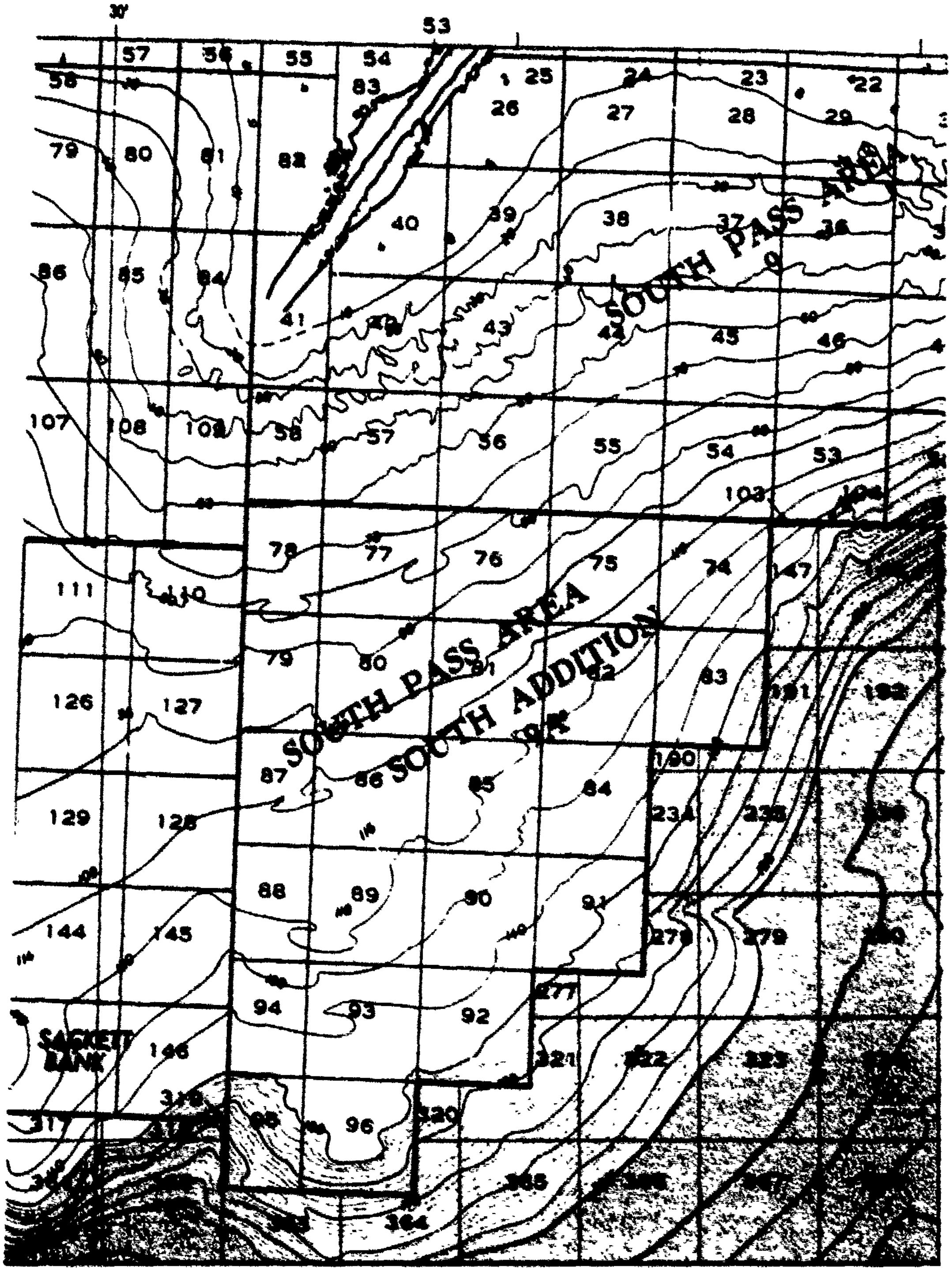


Figure 2-4. (U) Example of a NOAA Bathymetric Chart (U)

(U)

Mexico and Caribbean Sea to provide bathymetric cross-sections along arbitrarily selected tracks (Van Wyckhouse, 1973). Requests for SYNBAPS tracks should be made through LRAPP.

2.2 (U) Weather and Climatology (U)

2.2.1 (U) Description (U)

(U) The Gulf of Mexico and the Caribbean Sea have experienced on the order of five tropical storms or hurricanes each year. August, September and October have had three quarters of the occurrences during the period 1886-1957 (Weather Bureau, 1959). Secondary storm tracks, i.e., tracks along which there has been a moderate concentration of individual storm centers, can be drawn for these three months only. In August, two parallel tracks can be established, each moving west northwest while separated by the land masses of Hispaniola and Cuba. In September, the more northern of the two swings northward avoiding the Gulf-Caribbean area while the remaining southern track is joined by a third track originating near Panama and moving north northwest. A fourth track begins in the mid Gulf south of Alabama and moves northeast across the Florida penninsula. In October, the two westerly tracks south of Cuba veer over the western tip of Cuba and proceed northeasterly over the lower half of Florida.

(U) In the Gulf of Mexico, during August through October, the dominant directions of movement and approximate speed of travel of the storms were as follows: August - northwest and west at 12 knots; September - northwest and north at 12 knots; and October - northeast, north and northwest at 11 knots. In the Caribbean Sea the dominant direction of movement and approximate speed of travel, during this time period, were as follows: August - northwest and west at 13 knots; September - northwest and west at 12 knots; and October - northwest and north at 8 knots (Weather Bureau, 1959).

(U) Surface winds in the Gulf of Mexico are predominately easterly (including northeast and southeast) and account for approximately 65% of the total. Half of these (about 30% of all winds) were greater than ten

(U)

knots. The months of June, July and August are the calmest. In the Caribbean Sea the surface winds are easterly with approximately 70% of all winds from this direction. Forty percent of all winds were greater than ten knots. The months of September, October and November were the calmest (Weather Bureau, 1959; and NOO, 1963, 1972).

(U) The waves in the Gulf of Mexico and Caribbean are also predominately from the east. During the autumn and winter the seas are calm (or less than 1 ft) 14% of the time and are greater than 5 feet in height 9% of the time. Five percent of the time swells are greater than 12 feet. Approximately half of the waves have periods of less than 5 seconds and 90% less than 9 seconds. In the spring and summer the waves seldom (4% of the time) exceed 5 feet. The exception to this is August in the Caribbean where such waves occur 16% of the time. The swells in both the Gulf and Caribbean exceed 12 feet only 2% of the time. Seventy percent of the waves have periods less than 5 seconds while 90% are less than 9 seconds. (Weather Bureau, 1959; NOO, 1963, 1972)

2.2.2 (U) Effects on Acoustic Properties of the Area (U)

(U) Tropical storms and hurricanes have two potentially significant effects relative to the acoustic properties of the Gulf of Mexico and the Caribbean: 1) the mechanical mixing process at and near the surface is intensified, which can result in surface duct formation and broadening; and 2) surface and near-surface water temperature (and sound speed) can be reduced. Critical depth can be reduced by as much as 250 meters as a result of a storm. Surface winds have the effect of increasing the ambient noise especially at high frequency.

2.3 (U)Ocean Currents and Water Masses (U)

2.3.1 (U) Description (U)

(U) Surface circulation in the Caribbean Sea and Gulf of Mexico region is largely under the influence of the upper-layer transport system of the western North Atlantic Ocean. The Atlantic northeast trade winds

(U)

drive the Caribbean Current, which is formed from the juncture of the North Equatorial Current and the Guiana Current. The relatively warm, saline North Atlantic Central Water in the Caribbean is diluted during the summer by the Amazon River outflow.

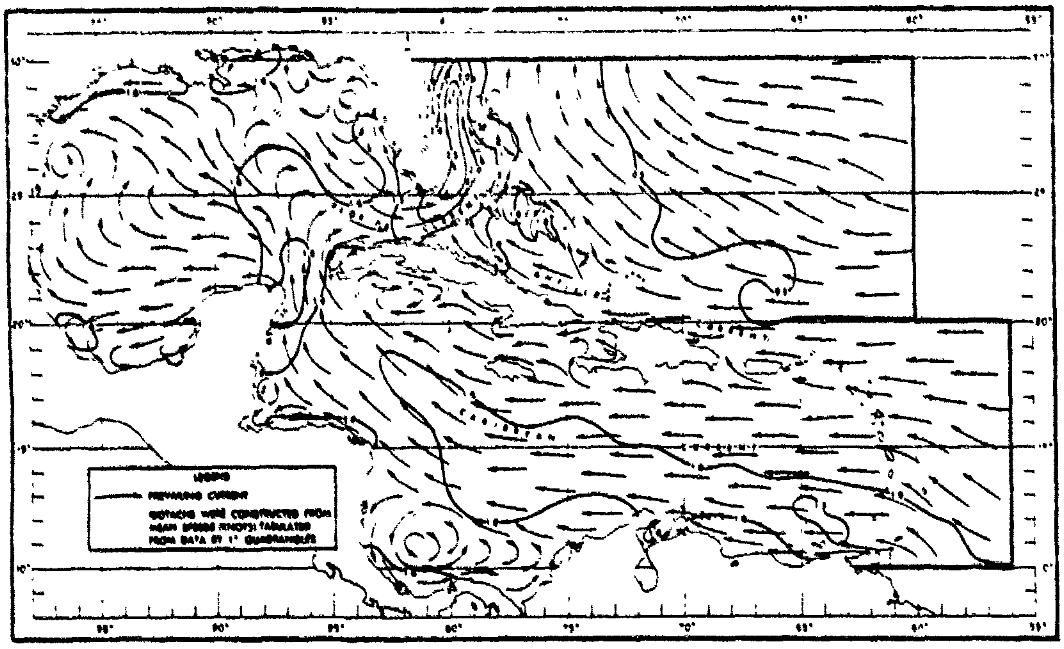
(U) Average seasonal current patterns and speeds for the Caribbean Sea and Gulf of Mexico are given in Figures 2-5 and 2-6. These figures were taken from the Environmental-Acoustic Atlas of the Caribbean Sea and Gulf of Mexico (NOO, 1972). Local variations from regional surface current patterns can be expected from wind.

(U) The subsurface water layers of the Caribbean Sea and Gulf of Mexico contain Subtropical Underwater characterized by a salinity minimum between 50 and 150 meters. This water is formed in the Equatorial Atlantic Ocean by evaporation (Wust, 1936) and transported to the Caribbean.

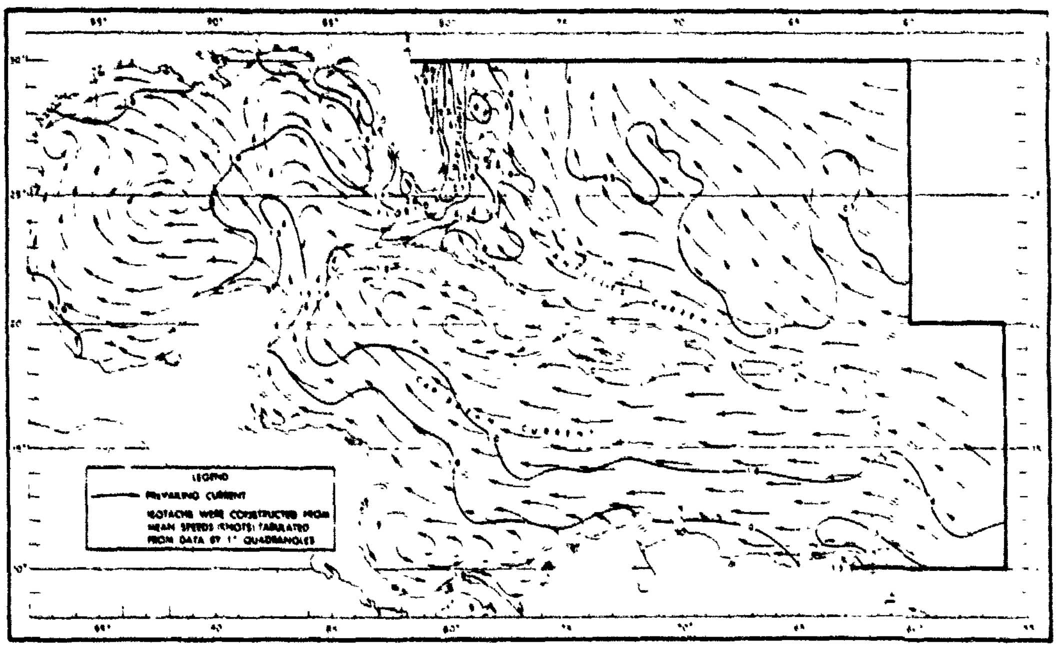
(U) Subantarctic Intermediate Water influences the water structure at intermediate depths. This water is formed in the Antarctic. The water sinks and spreads northward with a tongue extending along the coast of South America and entering the Caribbean (Wust, 1964). The water is characterized by a salinity minimum between 700 and 850 meters. Only a remnant of this low salinity water is found in the Gulf of Mexico (Nowlin & McLellan, 1967).

(U) The deeper layers of the Caribbean and Gulf of Mexico are occupied by Caribbean Deep Water, which has higher temperatures and salinities than correspondingly deep North Atlantic water (NOO, 1972).

(U) Returning to the nearsurface circulation, the Caribbean Current flows westward through the eastern and central Caribbean, then northward through the Yucatan Channel where it is known as the Yucatan Current. Countercurrents occur along the shores of the Caribbean, the most

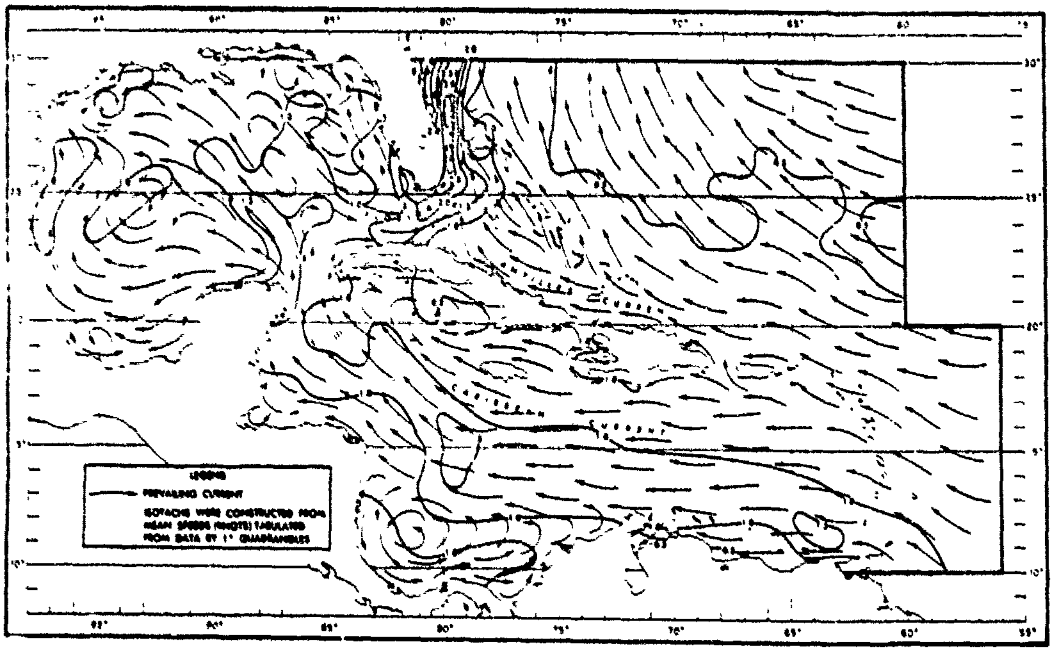


January - March

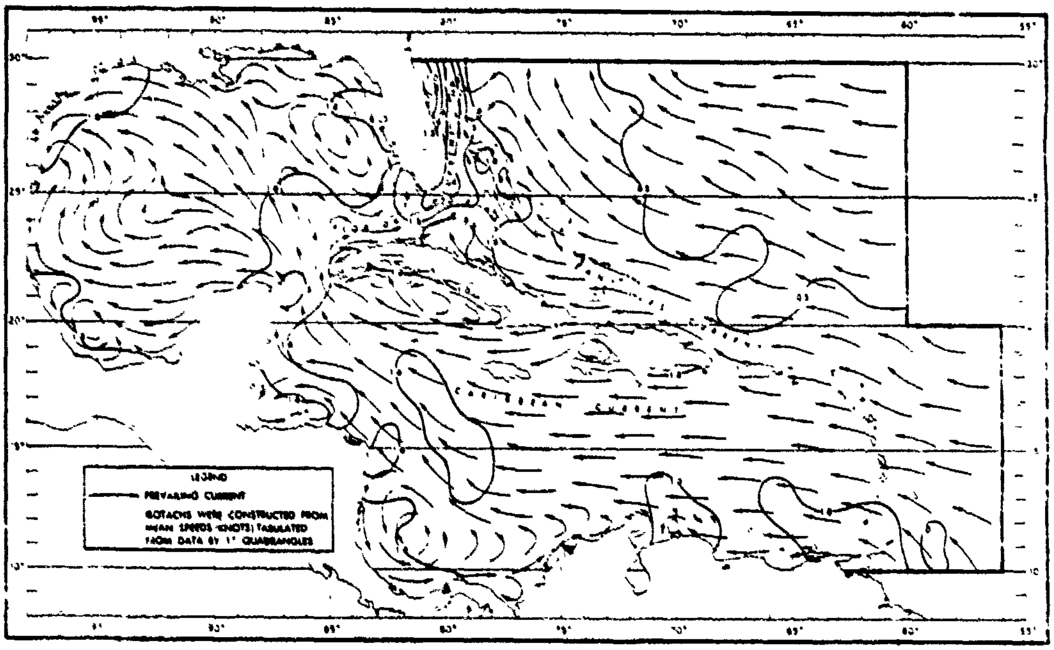


April - June

Figure 2-5. (U) Winter and Spring Current Patterns in the Gulf of Mexico and Caribbean Sea (U)



July - September



October - December

Figure 2-6. (U) Summer and Fall Current Patterns in the Gulf of Mexico and Caribbean Sea (U)

(U)

predominant being the cyclonic gyre off the coast of Panama and Colombia and the anticyclonic gyre in the Cayman Sea off the coast of Cuba (see Figures 2-5 and 2-6). Little is known of the annual cycle of the Cayman Sea gyre (Molinari, 1978).

(U) The Yucatan Current transports about 25 to 30 million cubic meters of water per second through the Yucatan Channel from the Caribbean into the Gulf of Mexico and Straits of Florida (Morrison & Nowlin, 1977). Average surface speeds of 1 knot are measured near the eastern edge of the channel, increasing to approximately 1.5 knots near the western edge, 20 to 30 miles east of Yucatan. Measurements of current speeds near 4 knots have been reported in the Yucatan Channel (Molinari & Cochrane, 1972). The maximum speeds are attained in the spring or early summer. The surface speeds drop sharply during mid-fall to a minimum in October or November. There is evidence that, at least seasonally, a south-southwestward countercurrent exists along the Cuban coast and into the Caribbean (Harding & Nowlin, 1966).

(U) As the Yucatan Current extends into the Gulf of Mexico it splits, with part flowing into the western Gulf over the Campeche bank, but with most of the volume flowing either east into the Straits of Florida or north to form the Loop Current of the eastern Gulf of Mexico. The Loop Current flows northward from the Yucatan Channel then turns clockwise to the east then southeast before flowing out of the Gulf through the Straits of Florida. The Loop Current and the anticyclonic gyres which separate from it are the major circulation features of the eastern Gulf of Mexico. The northern penetration of the Loop Current into the Gulf is roughly cyclic. Leipper and others have suggested a period of one year (Leipper, 1970: Maul, 1977; Molinari, 1978). Figure 2-7, from Maul, 1975, indicates the position of the Loop Current as inferred from the 22°C isotherm at 100 meters depth over the period August, 1972 - September 1973. While the Loop Current appears to grow and decay within

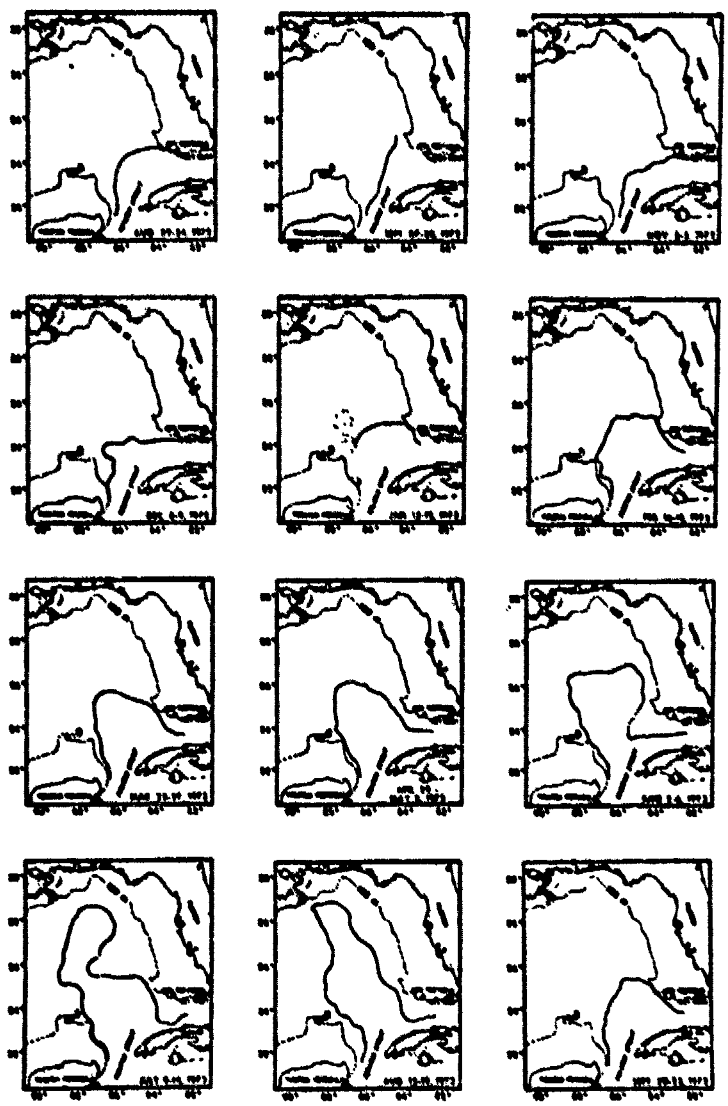


Figure 2-7 (U) Position of the Loop Current as Inferred from the 22°C Isotherm (U)

(U)

the Gulf with an annual cycle, the year-by-year variability in the pattern of the current is significant (Maul, 1977). The maximum intrusion occurs during the summer, the minimum during the winter. However, as previously stated, this pattern shows great variability, maximum intrusions occasionally being observed in winter (Molinari, 1978). The eddy separation from the northern part of the Loop Current also exhibits variable and apparently annual behavior.

(U) According to calculations by Maul (Maul, 1977) a transport of about four million cubic meters per second of Yucatan surface water into the Gulf over that which leaves the Gulf through the Straits of Florida is required to account for the growth of the Loop Current. This in turn requires that there be a southward outflow near the bottom of the Yucatan Strait during this growth period of the Loop Current.

(U) Thompson has made calculations that show that changes to transport through the Yucatan Strait are not required for eddy separation from the Loop current (Thompson, Dana, 1979, personal communication). He suggests that the cyclic behavior of the Loop current is, in general, a result of eddy separation rather than changes in transport. The current intrudes northward into the Gulf, then a major eddy separates, the current re-connects in the south, where it again reverses its northward movement. The period between major eddy separations ranges between six months and a year and is dependent upon both the distribution as well as the magnitude of the transport through the Yucatan Strait.

(U) The major circulation feature of the western Gulf of Mexico appears to be an elongated anticyclonic gyre whose axis tends northeast-southwest and is located over the deep portions of the western Gulf. There exists some evidence that this gyre is driven by the Loop Current, either directly or by pinched-off eddies. It is also suggested (Sturges & Blaha, 1976) that the gyre is driven by wind. The flow is

(U)

observed to be strongest in winter and summer. In general, the currents in the western Gulf are weak, not well defined, and appear to vary temporally in locations and intensity (Harding & Nowlin, 1966).

(U) Surface water leaves the Gulf of Mexico through the Straits of Florida where the Florida Current joins the Antilles Current to form the Gulf Stream. Computations of transport through the Straits of Florida are in good agreement with those of inflow through the Yucatan Channel. It is interesting to note that estimates of discharge by the Mississippi River and other rivers into the Gulf is less than 25,000 cubic meters per second (Holman, 1968) while the excess of evaporation over precipitation is estimated to be about 20,000 cubic meters per second (Maul, 1977). Figure 2-8, taken from NOO Pub. No. 700, gives an indication of the nature of subsurface currents in the Straits of Florida.

2.3.2 (U) Effects on Acoustic Properties of the Area (U)

(U) The flow of warm, saline Caribbean water from the Yucatan Channel, which is then transported by the Loop Current into the Gulf of Mexico, can be expected to introduce significant variations in the sound speed structure over the relatively confined geographic area through which the current passes. This is illustrated in Figure 2-9 where the approximate sound speed (computed using only temperature and depth) is plotted for two locations separated by only 118 miles across the Loop Current. The data plotted correspond to depths where the 15°, 20°, and 25°C isotherms were measured. It will be noted that at a depth of 200 meters the sound speed differs by 22 m/s over the 118 mile separation. The data were taken from measurements made in May, 1972 (Morrison & Nowlin, 1977).

(U) In addition to the pronounced variations in sound speed structure that can be expected from the Loop Current, a certain degree of ambient noise dependence associated with commerical and sports fishing may

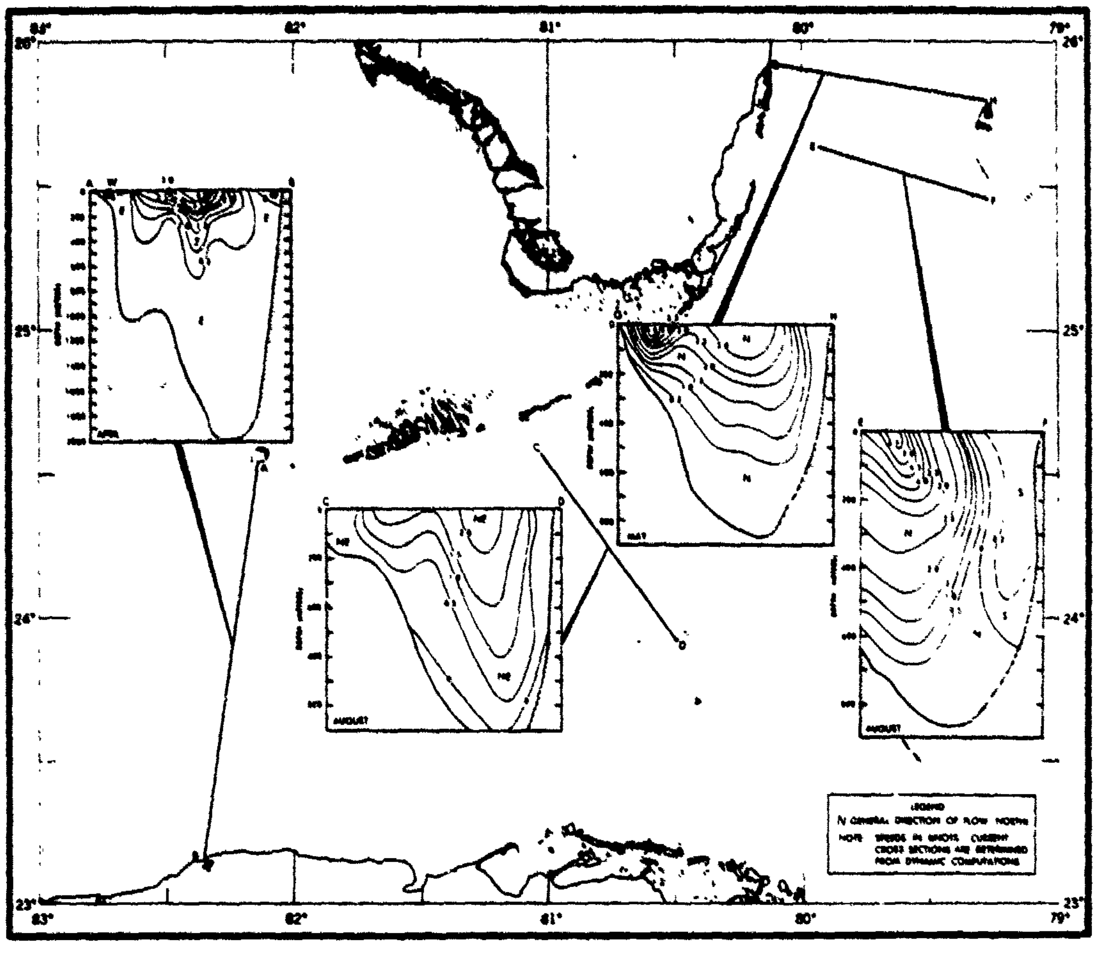


Figure 2-8. (U) Subsurface Currents in the Strait of Florida (U)

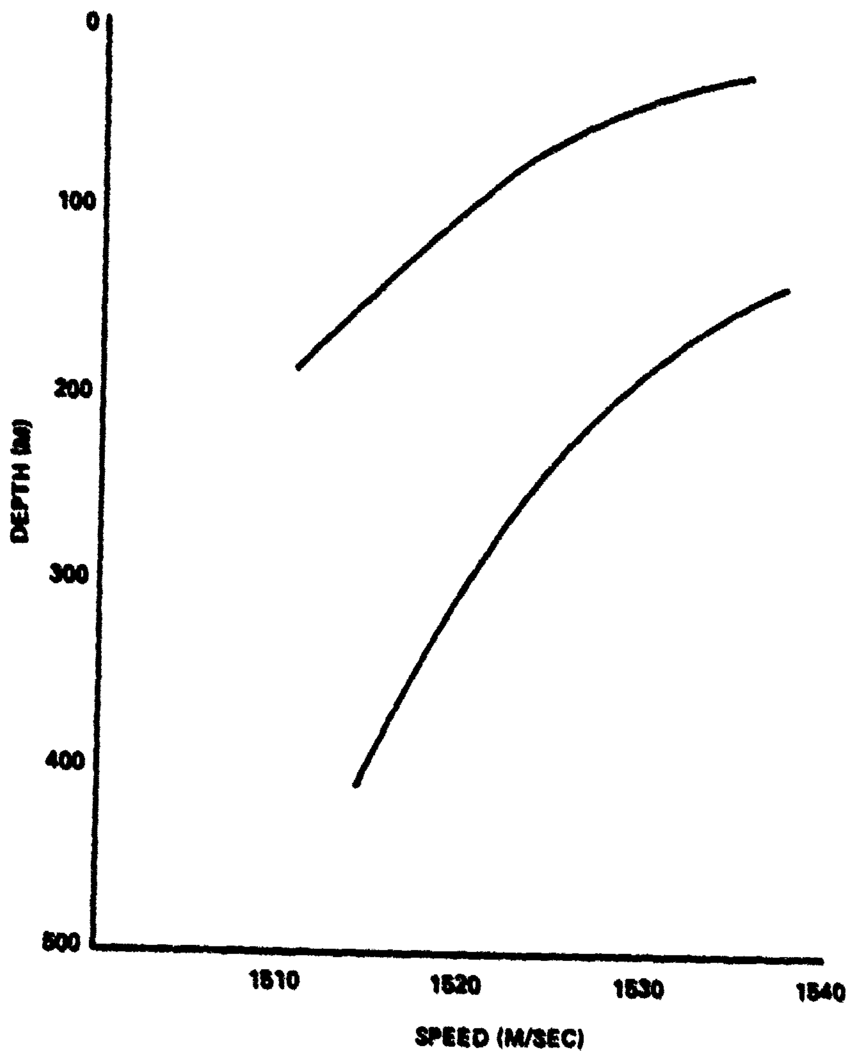


Figure 2-9. (U) Approximate Sound Speed Profiles at Two Points Separated 118 Miles Across the Loop Current. Sound Speed Computed from Temperature and Depth Only. (U)

(U)

also be found with the Loop Current. Plankton, the base of the food chain, are concentrated along the boundary zone of the current. Thus, with changes in the pattern of the Loop Current, the prime fishing areas also change (Jones, 1973).

2.4 (U) Sound Speed Structure (U)

2.4.1 (U) Data Locations and Sources (U)

(U) The principal source of sound speed profiles is the National Oceanographic Data Center (NODC). NODC maintains archival ocean-station data files of measured temperature and salinity from which they compute sound speed. Individual temperature-salinity-sound speed profiles and sound speed summaries are available from NODC. The NODC summaries present the minimum, maximum, and mean sound speeds of the data in their files for any desired set of one degree squares and months as well as the standard deviation of the data set. An inventory of profiles currently available from NODC for the Gulf of Mexico and Caribbean Sea west of 70° west longitude by one degree squares is given in Figures 2-10 through 2-21 for each month of the year. The NODC data have also recently been incorporated into the LRAPP data bank maintained by DANALYT.

(U) As an improvement to the NODC summary approach, from an acoustic standpoint, the Acoustic Environmental Support Detachment (AESD) developed a sound-speed profile retrieval system (RSVP) (Audet & Vega, 1974). RSVP selects up to three representative profiles for any temporal and spatial specification using as a base the horizontal and vertical sound speed characteristics of all acceptable profiles in the area and time of interest. An acceptable profile is considered to be one with sufficient measurements of temperature and salinity at depth to provide sound-speed values for specific standard depth levels to the maximum depth specified. A model profile, considered the most typical of the entire set of profiles available, is generally included with each analysis. The model profile is

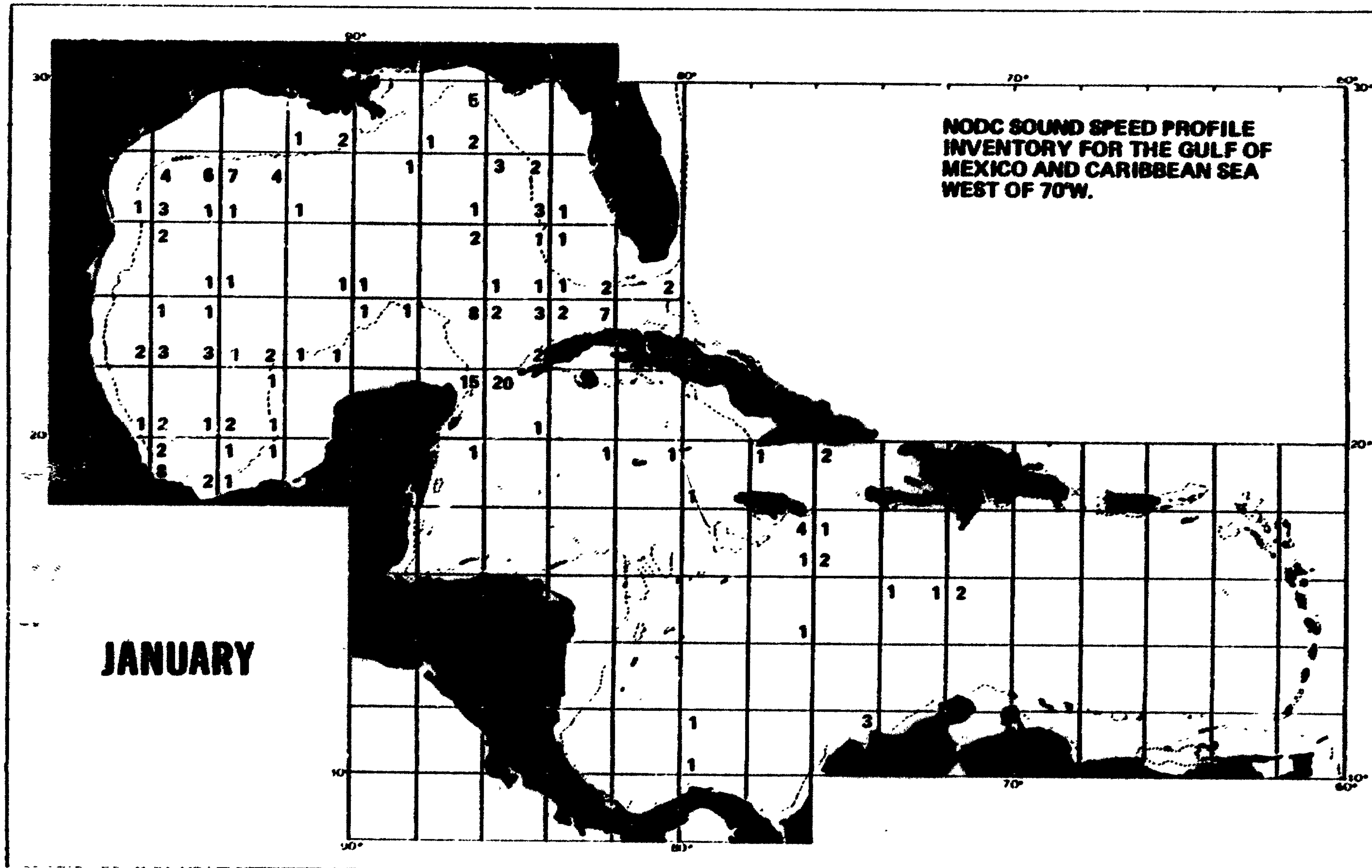


Figure 2-10. (U) NODC Sound Speed Profile Inventory for January by 1° Squares (U)

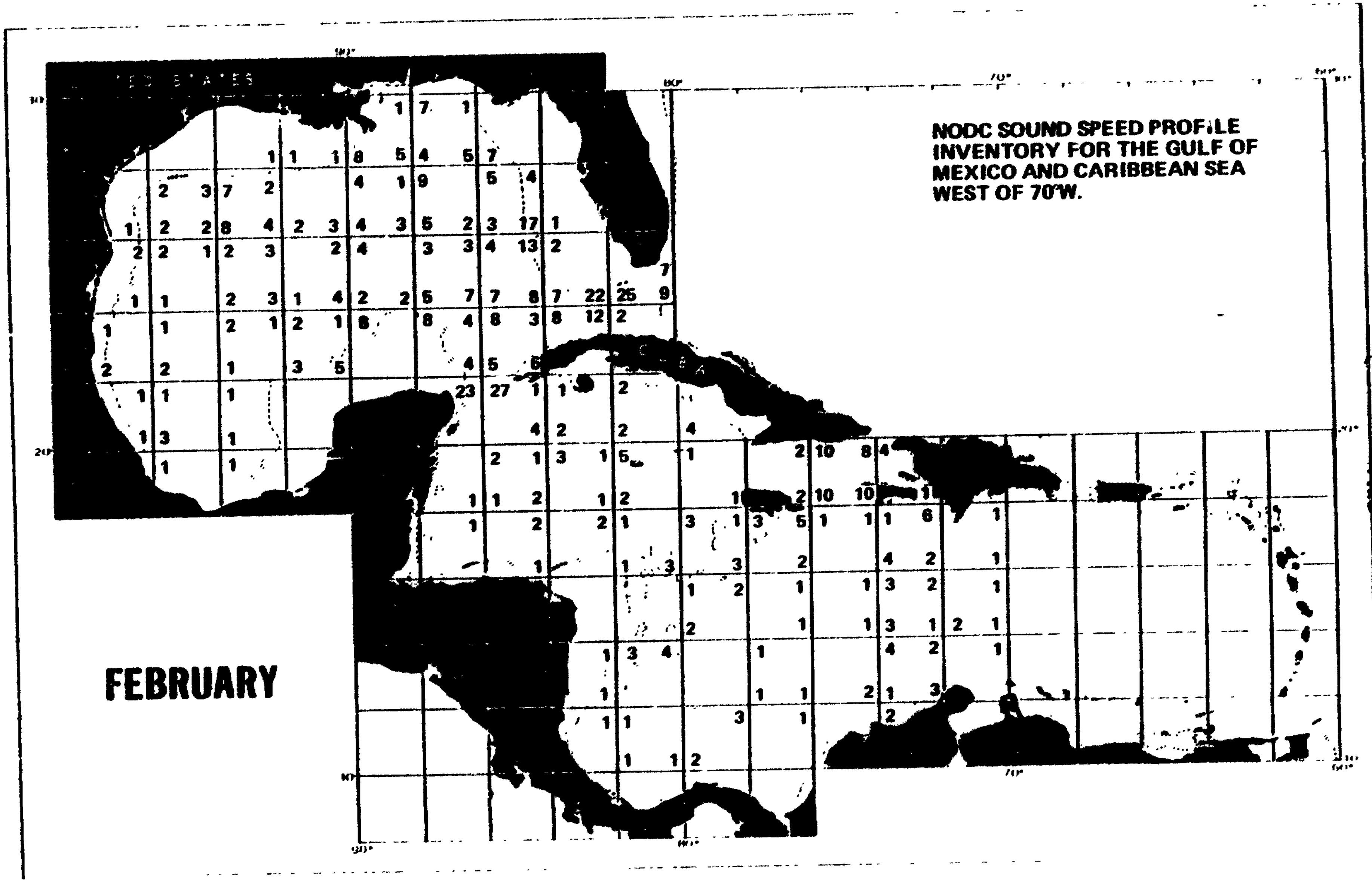


Figure 2-11. (U) NODC Sound Speed Profile Inventory for February by 1° Squares (U)

Figure 2-12. (U) NODC Sound Speed Profile Inventory for March by 1° Squares (U)

Figure 2-13 (U) NODC Sound Speed Profile Inventory for April by 1° Squares (U)

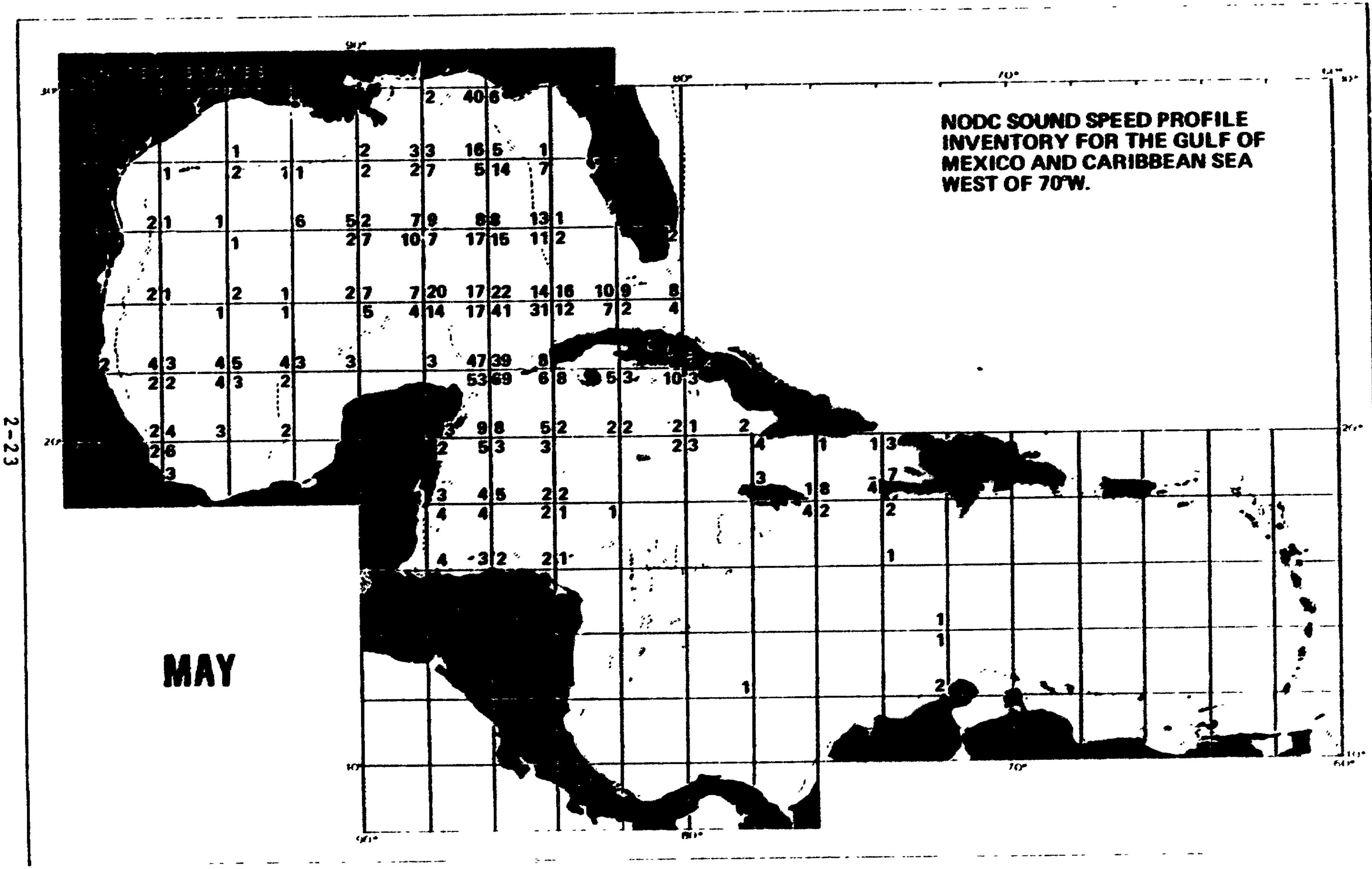


Figure 2-14 (U) NODC Sound Speed Profile Inventory for May by 1° Squares (U)

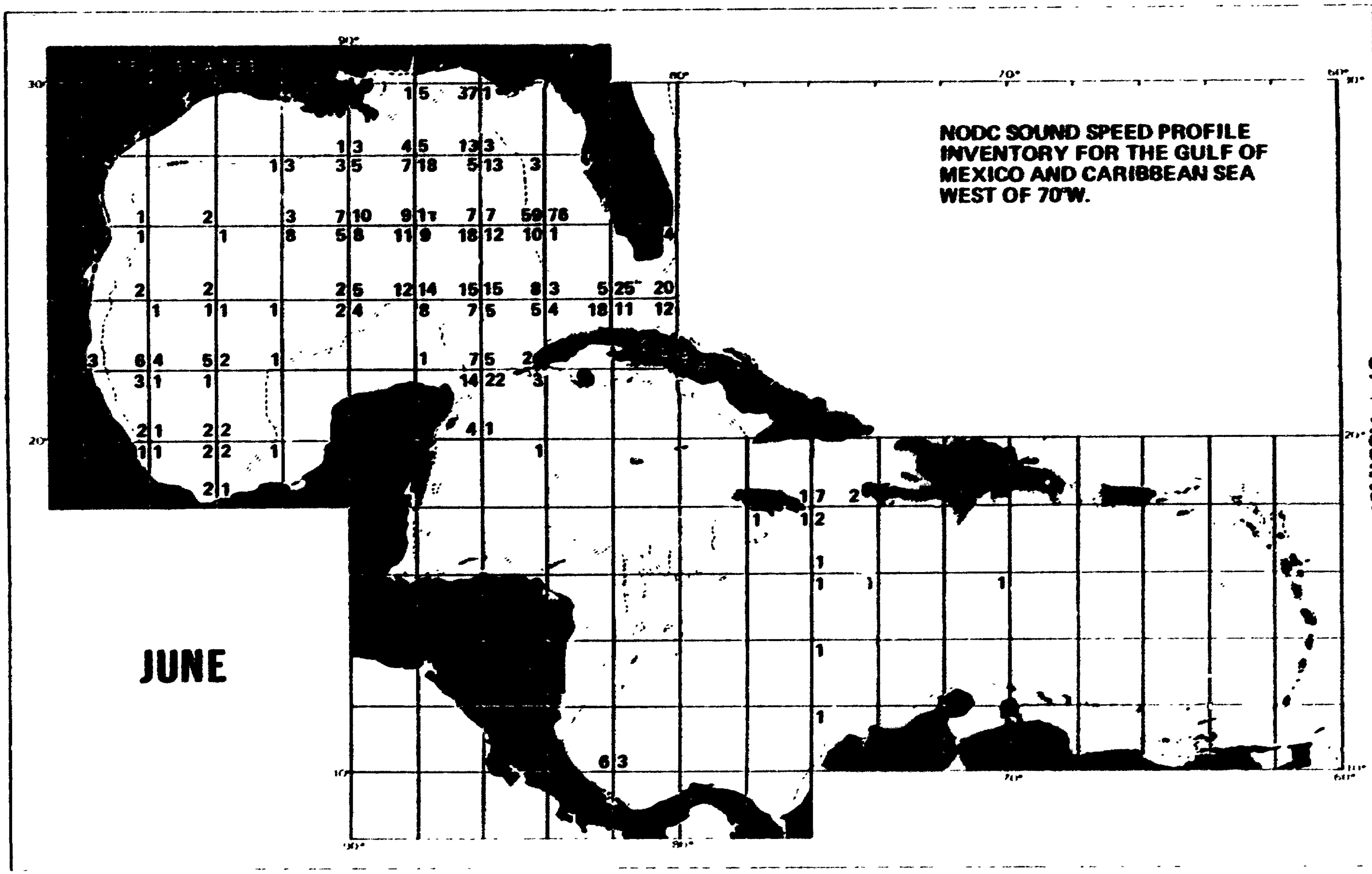


Figure 2-15 (U) NODC Sound Speed Profile Inventory for June by 1° Squares (U)

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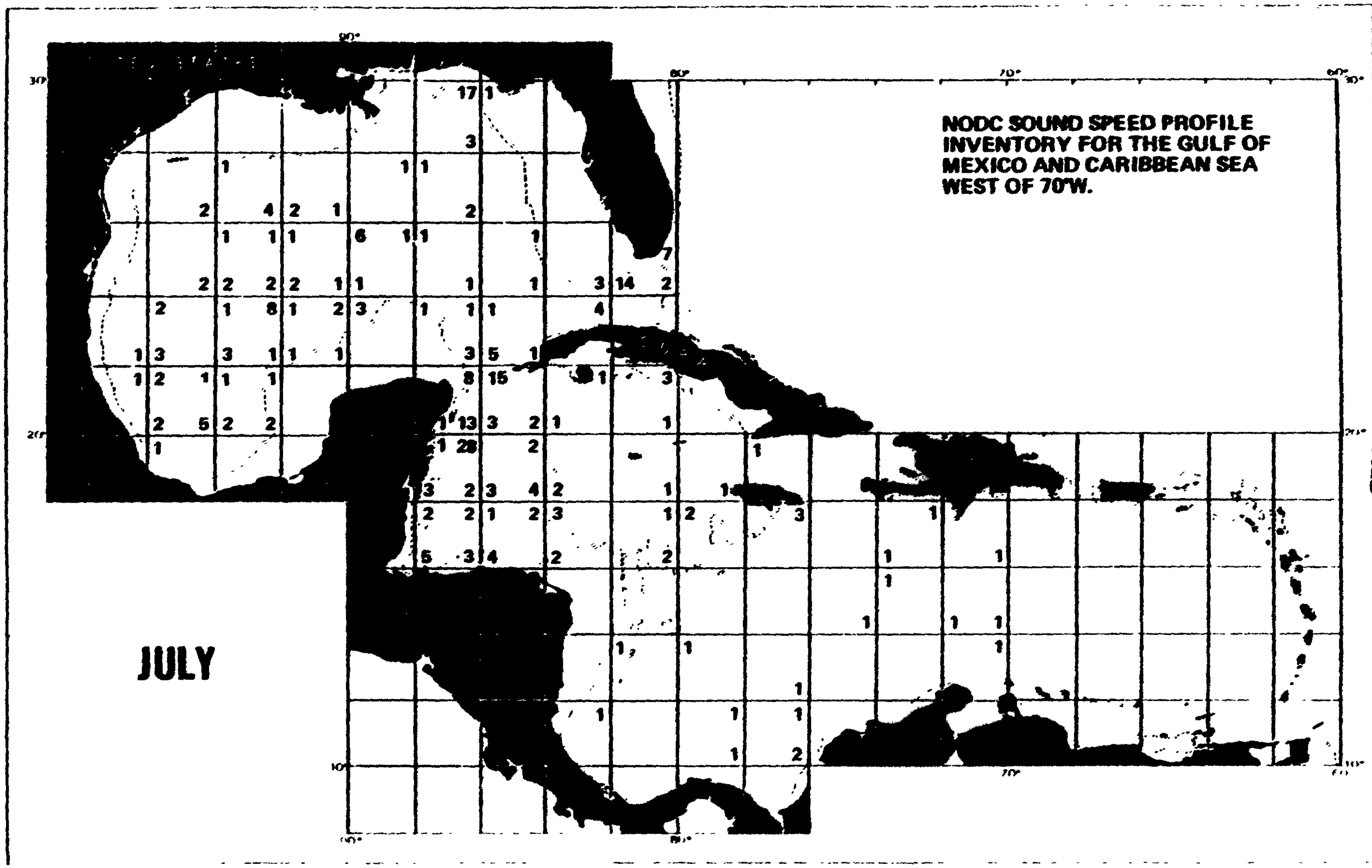

Figure 2-16. (U) NODC Sound Speed Profile Inventory for July by 1° Squares (U)

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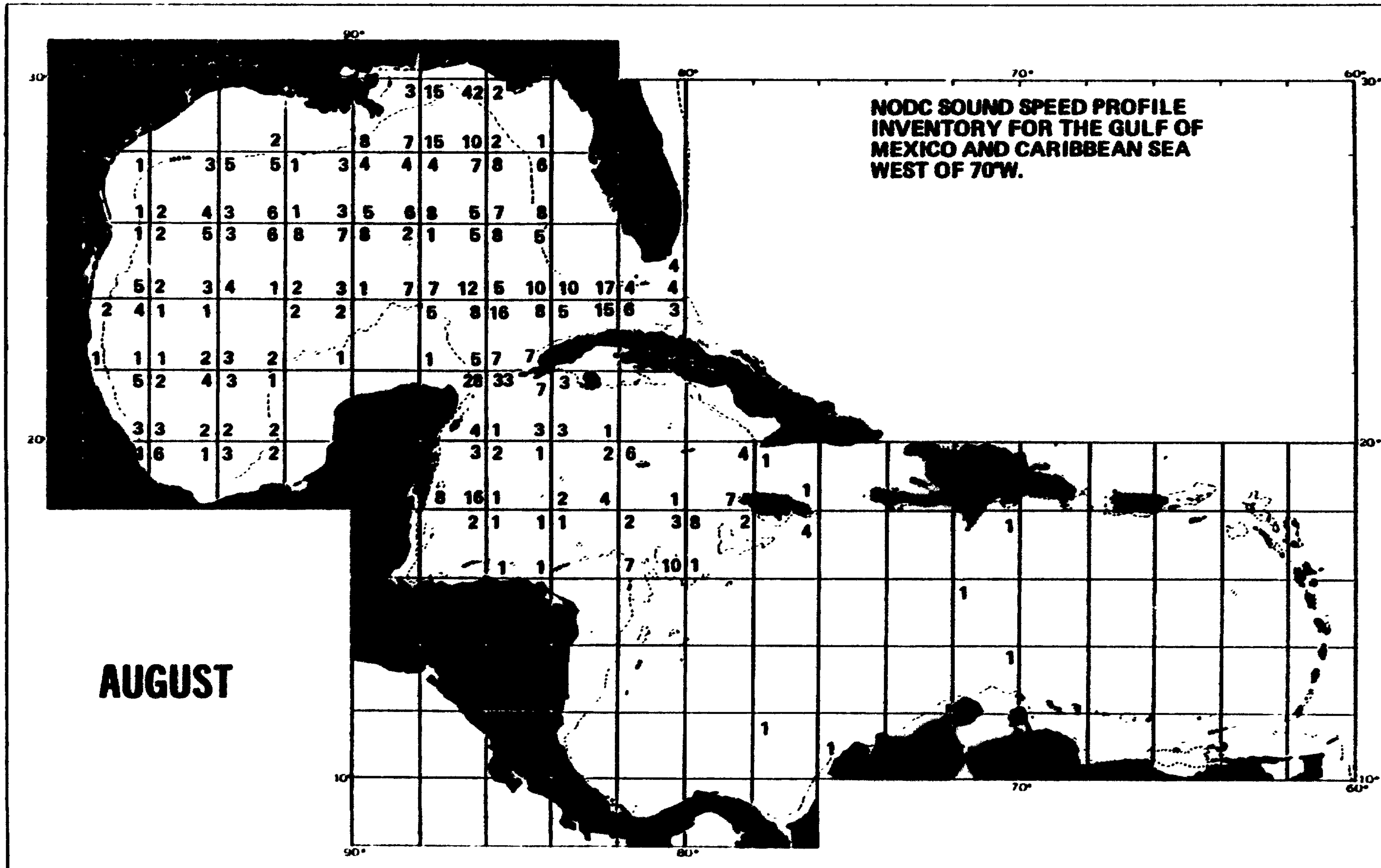

Figure 2-17. (U) NODC Sound Speed Profile Inventory for August by 1° Squares (U)

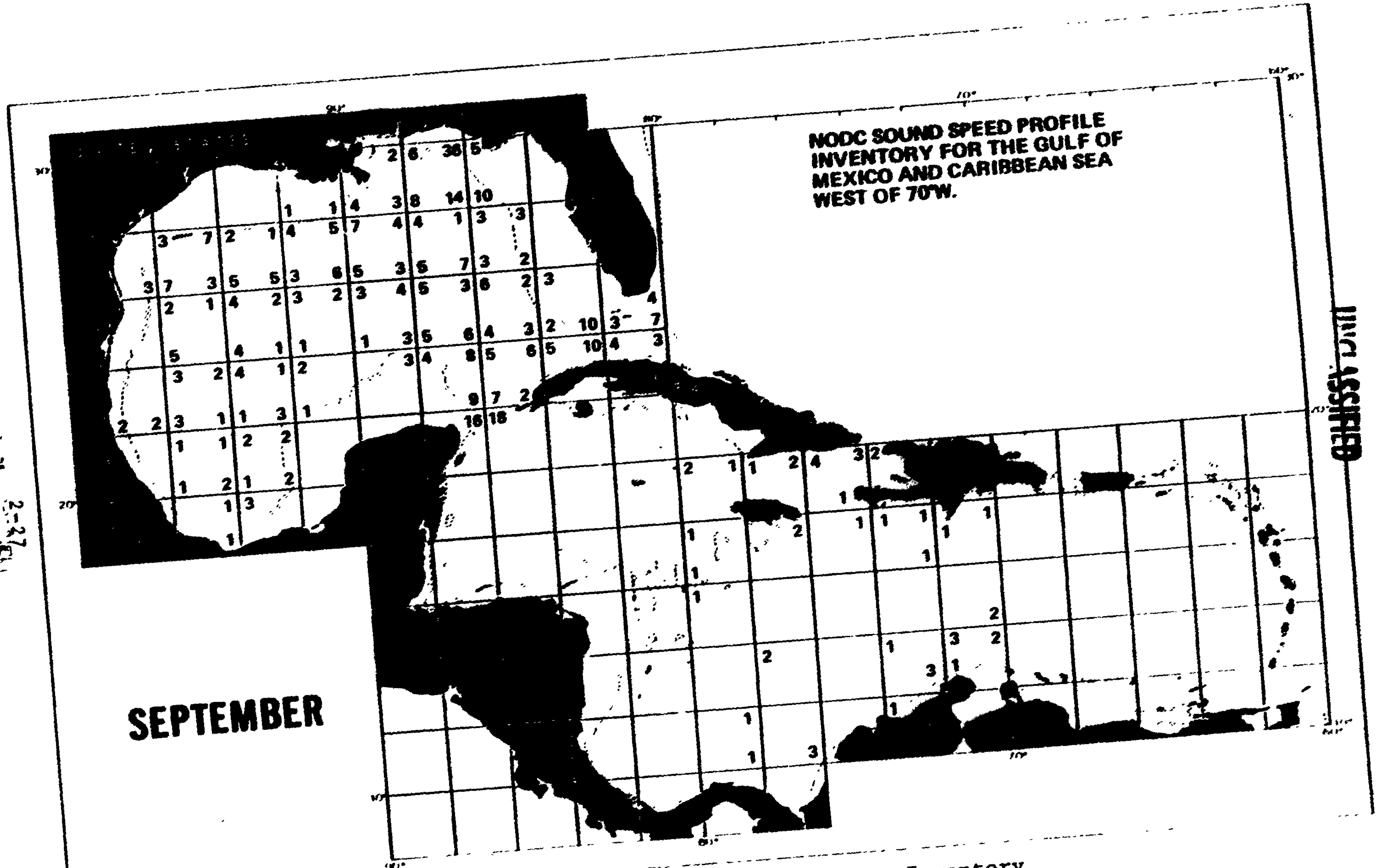

Figure 2-18. (U) NODC Sound Speed Profile Inventory for September by 1° Squares (U)

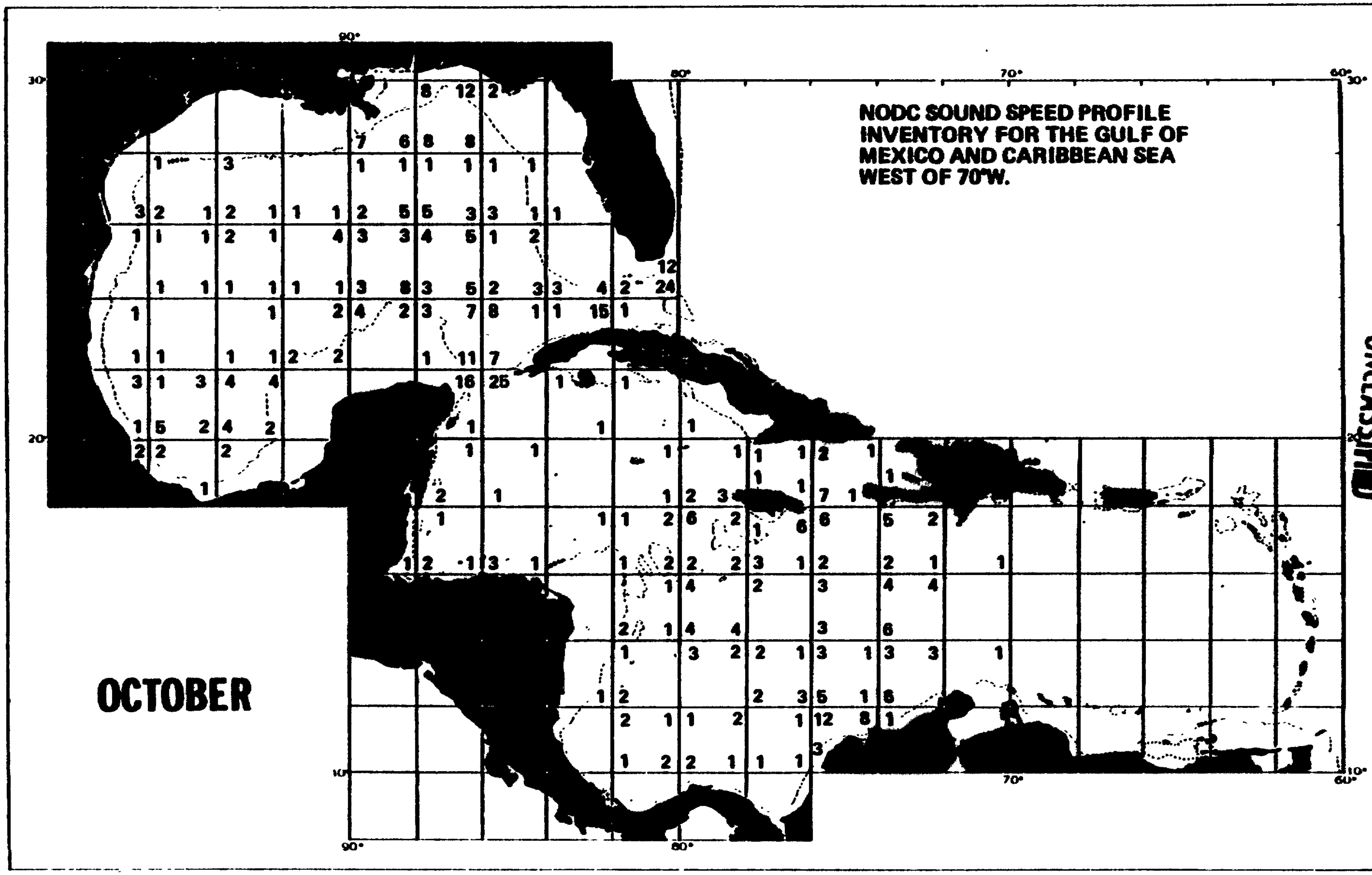

Figure 2-19. (U) NODC Sound Speed Profile Inventory for October by 1° Squares (U)

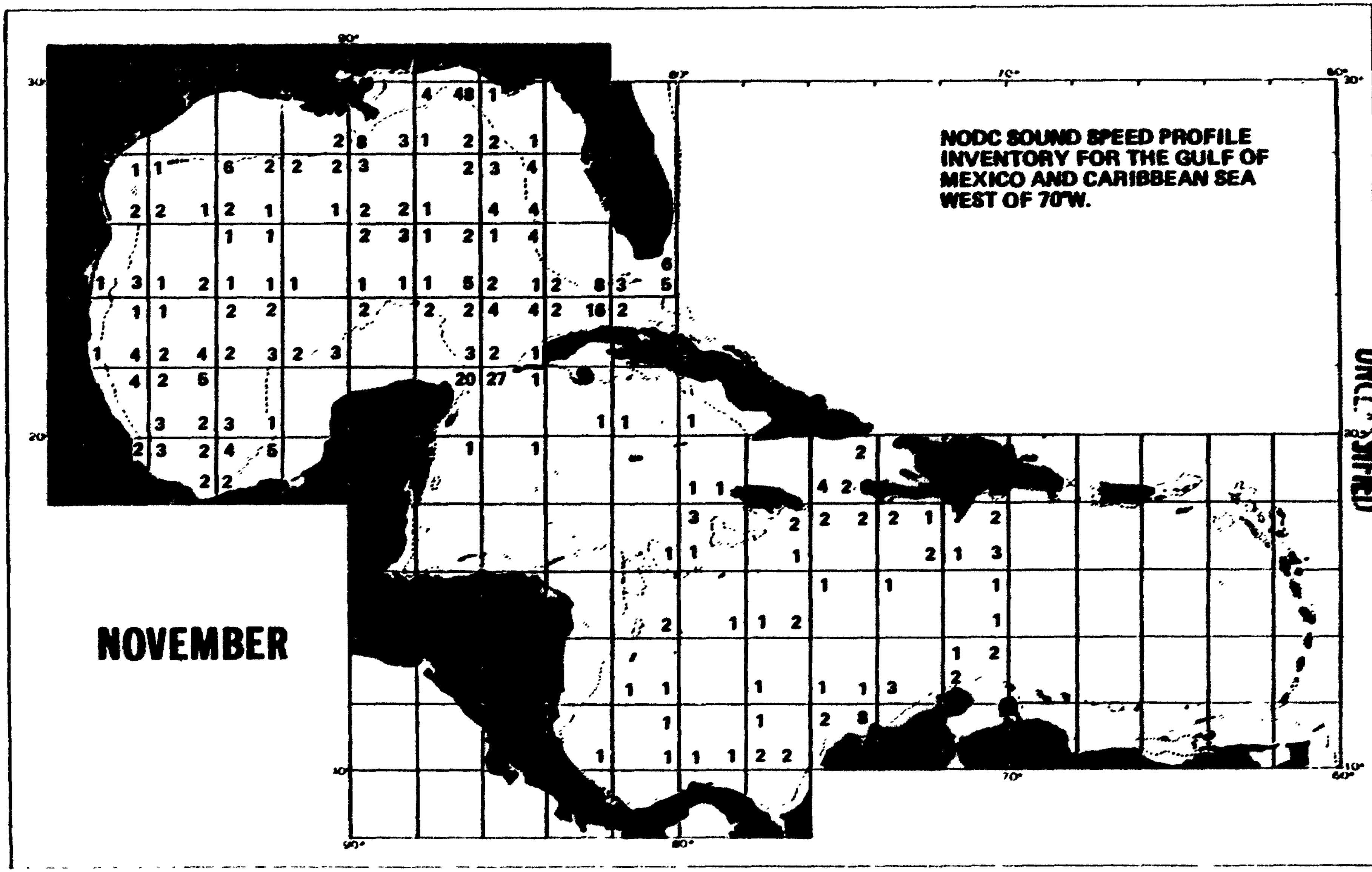

Figure 2-20 (U) NODC Sound Speed Profile Inventory for November by 1° Squares (U)

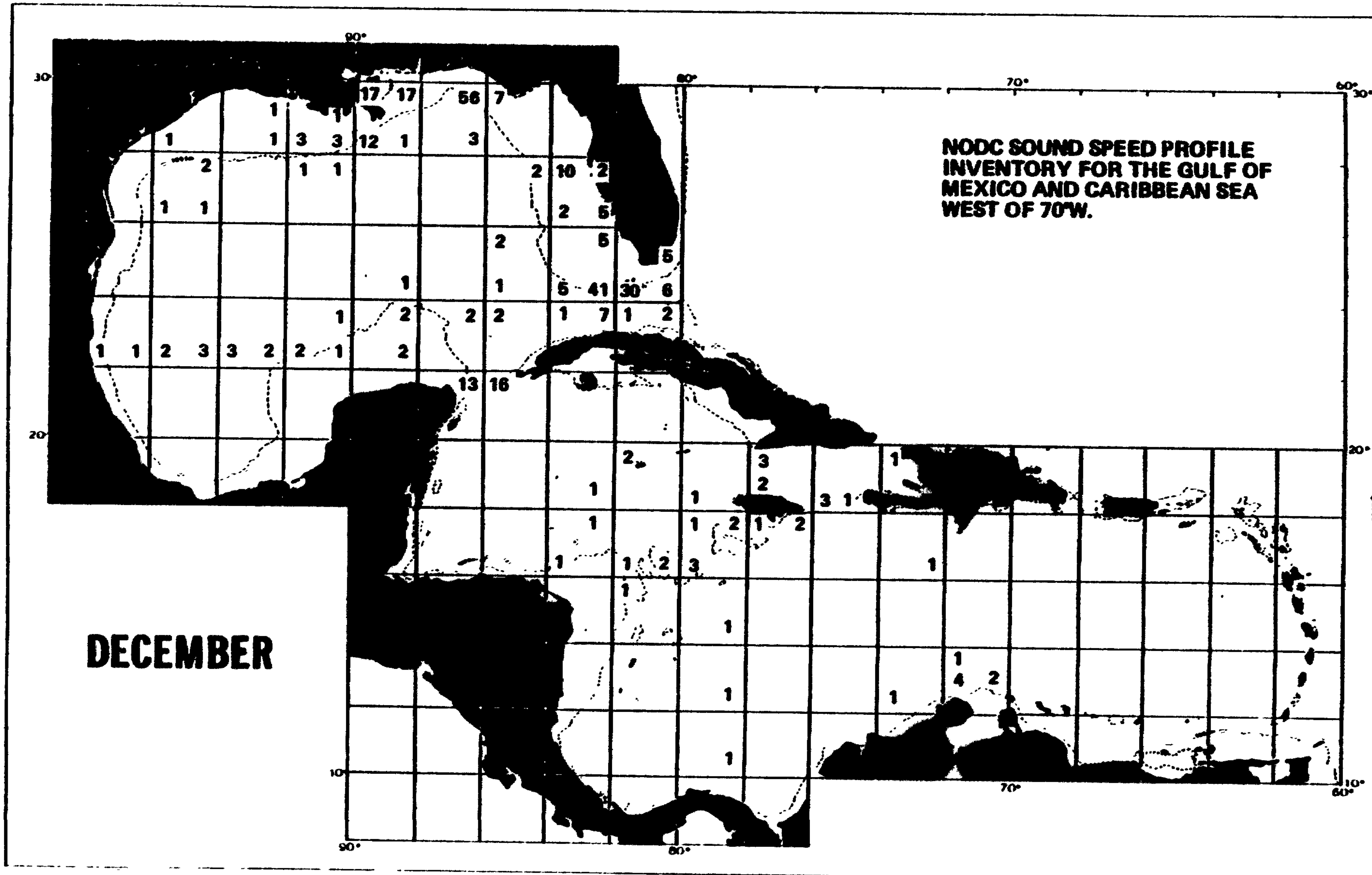

Figure 2-21. (U) NODC Sound Speed Profile Inventory for December by 1° Squares (U)

(U)

also an actual measured profile but is extended to the depth of the ocean floor in the area or to 10,000 meters if desired. The data base used by the RSVP system is the NODC data base of 1973.

2.4.2 (U) Selected Sound Speed Data (U)

(U) Selected sound speed profiles are illustrated in Figures 2-22 through 2-31. Figure 2-22 is a locator map for the profiles. These data were taken from the Environmental-Acoustics Atlas of the Caribbean Sea and the Gulf of Mexico (NOO, 1972). The profiles are actual profiles, not averaged data. They cover all months in each basin where data were available at the time the Atlas was prepared.

2.4.3 (U) Adequacy of Data to Provide Profiles Along Arbitrary Tracks (U)

(U) The adequacy of available sound speed data to provide profiles along arbitrary tracks ranges from excellent to marginal in the Gulf-Caribbean region depending on location and month. For example, the data are considered marginal in the northern Caribbean during the summer months whereas rather extensive measurements have been made in the Yucatan Channel.

(U) In general, sound speed data should be adequate for assessment purposes in the Gulf of Mexico and northern Caribbean.

2.5 (U) Depth Excess and Critical Depth (U)

2.5.1 (U) Discussion (U)

(U) Most of the Caribbean Sea and essentially all of the Gulf of Mexico are bottom-limited throughout the year. Only in the Cayman Trough and Venezuelan Basin is there a depth excess; i.e., a nonbottom-limited region where critical depth is shoaler than the bottom depth. During the summer critical depth deepens, which results in a reduction in the area in

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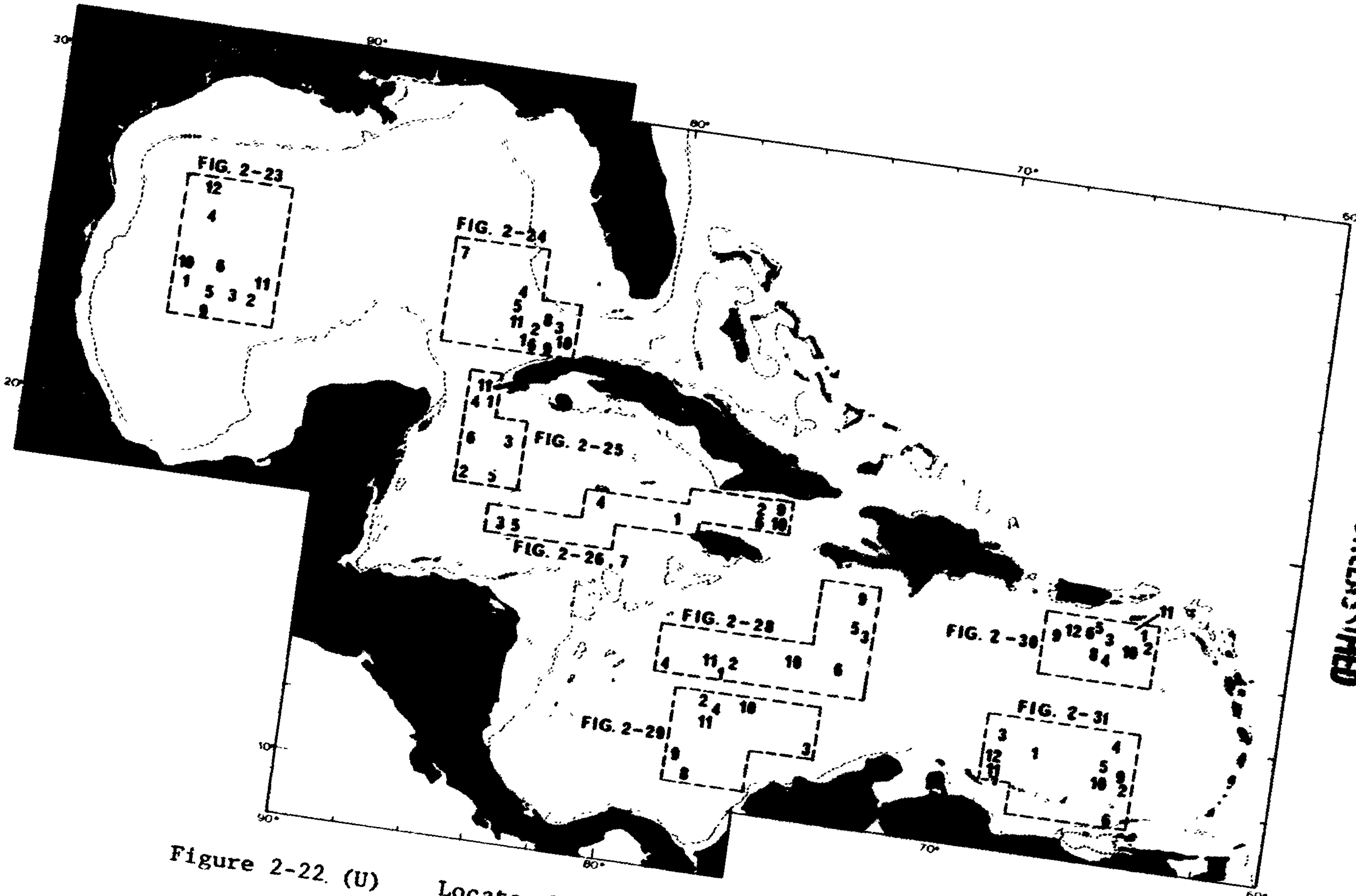

Figure 2-22 (U) Locator Map for the Sound Speed Profiles Illustrated in Figures 2-23 through 2-31. The Numerals Correspond to Location and Month. (U)

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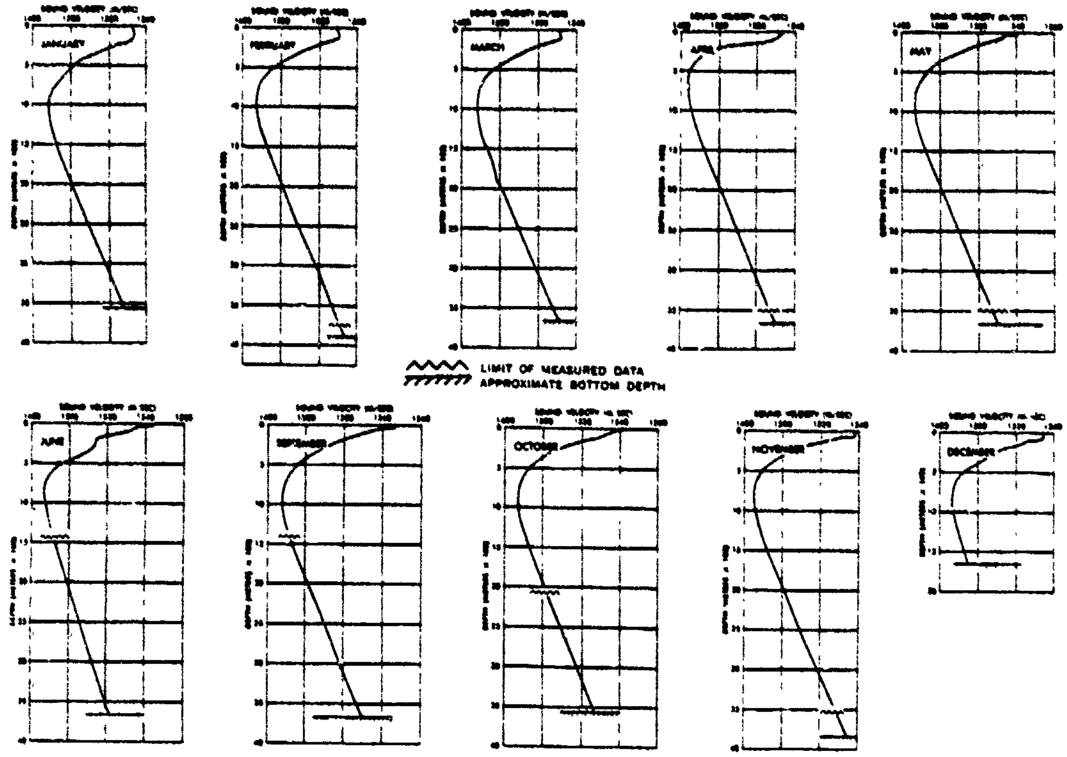

Figure 2-23. (U) Sound Speed Profiles in the West Mexico Basin (U)

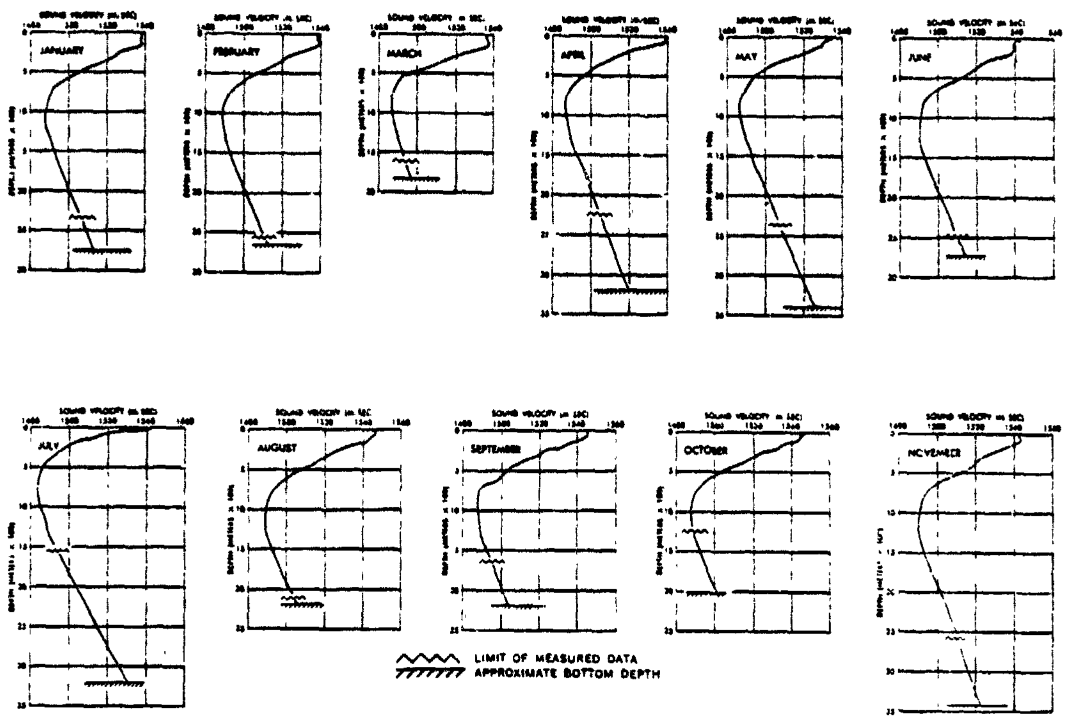

Figure 2-24. (U) Sound Speed Profiles in the East Mexico Basin (U)

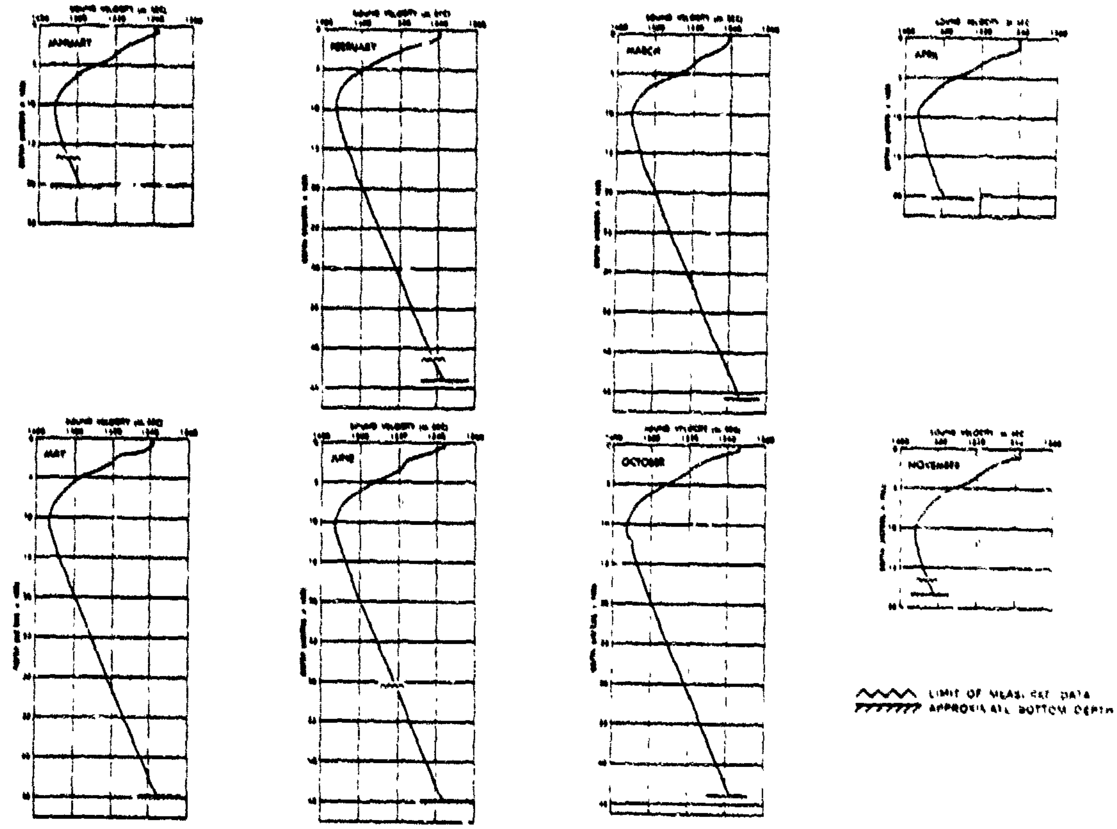

Figure 2-25. (U) Sound Speed Profiles in the Yucatan Basin (U)

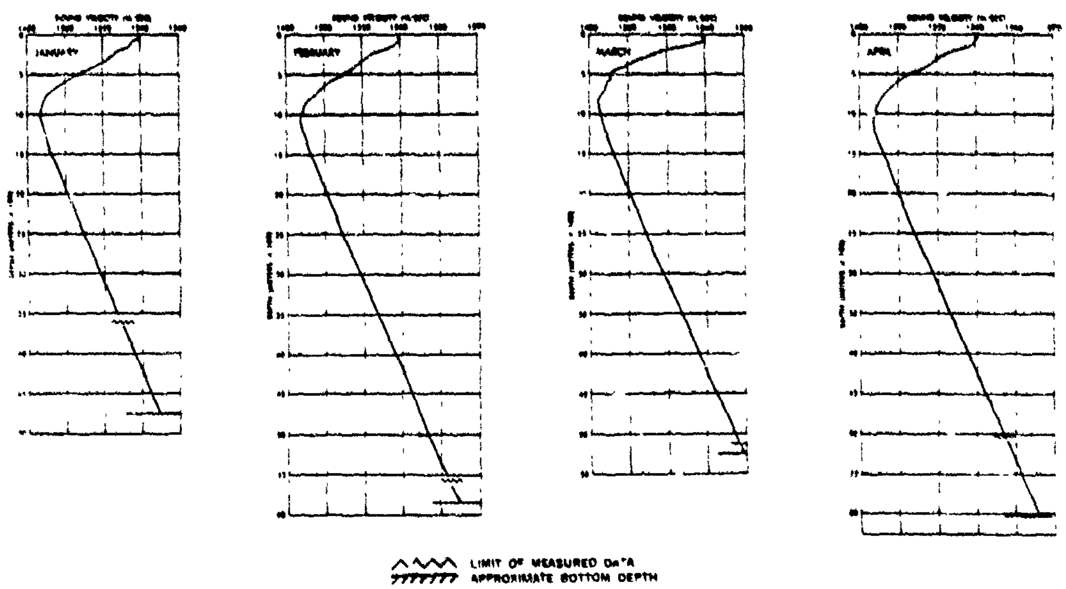

Figure 2-26. (U). Sound Sneed Profiles in the Cayman Trough (U)

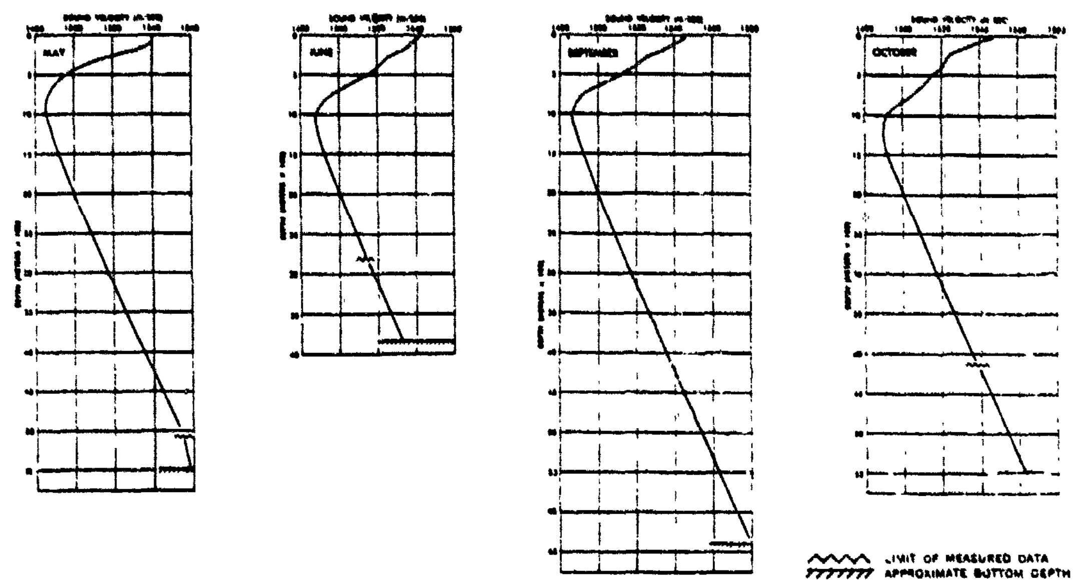

Figure 2-27 (U) Sound Speed Profiles in the Cayman Trough (continued) (U)

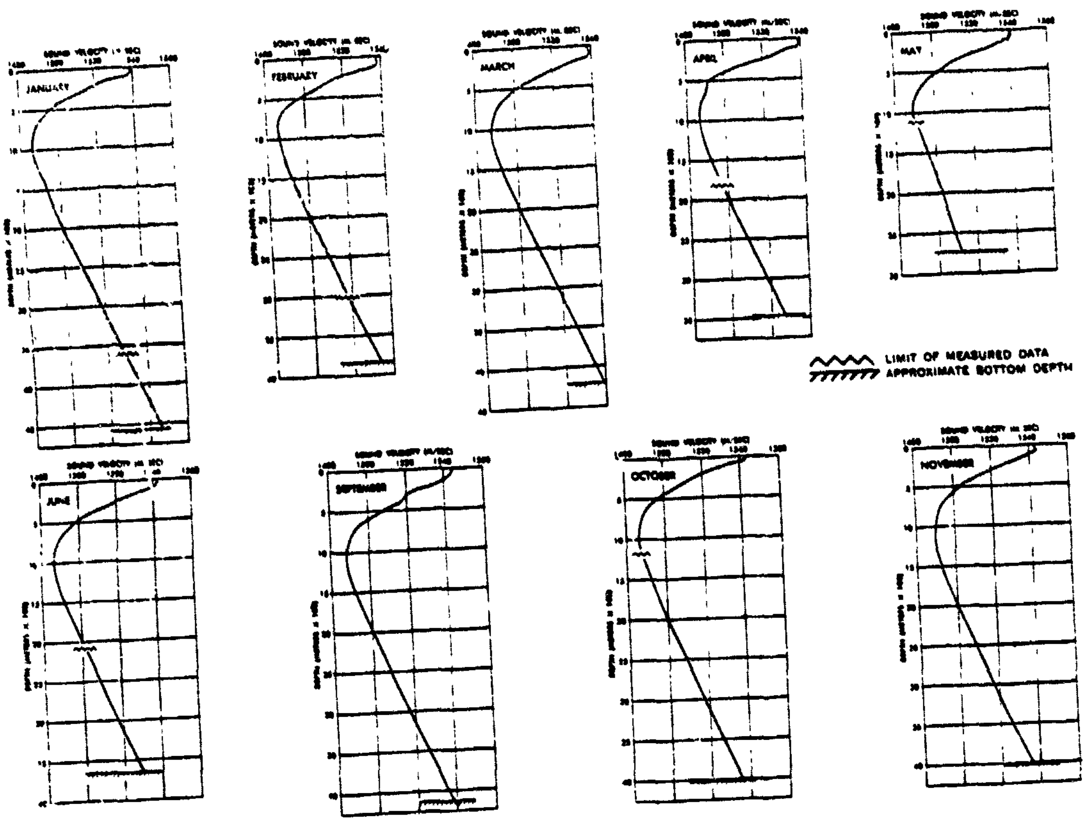

Figure 2-28. (U). Sound Speed Profiles in the North Colombian Basin (U)

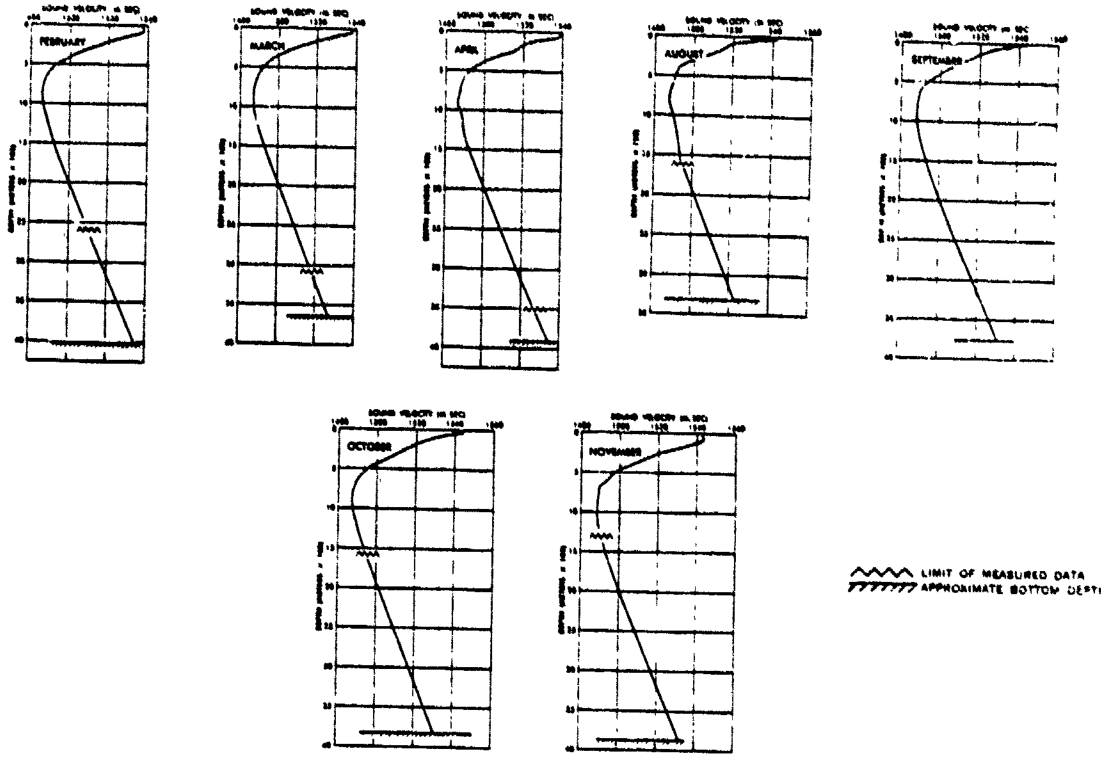

Figure 2-29. (U). Sound Speed Profiles in the South Colombian Basin (U)

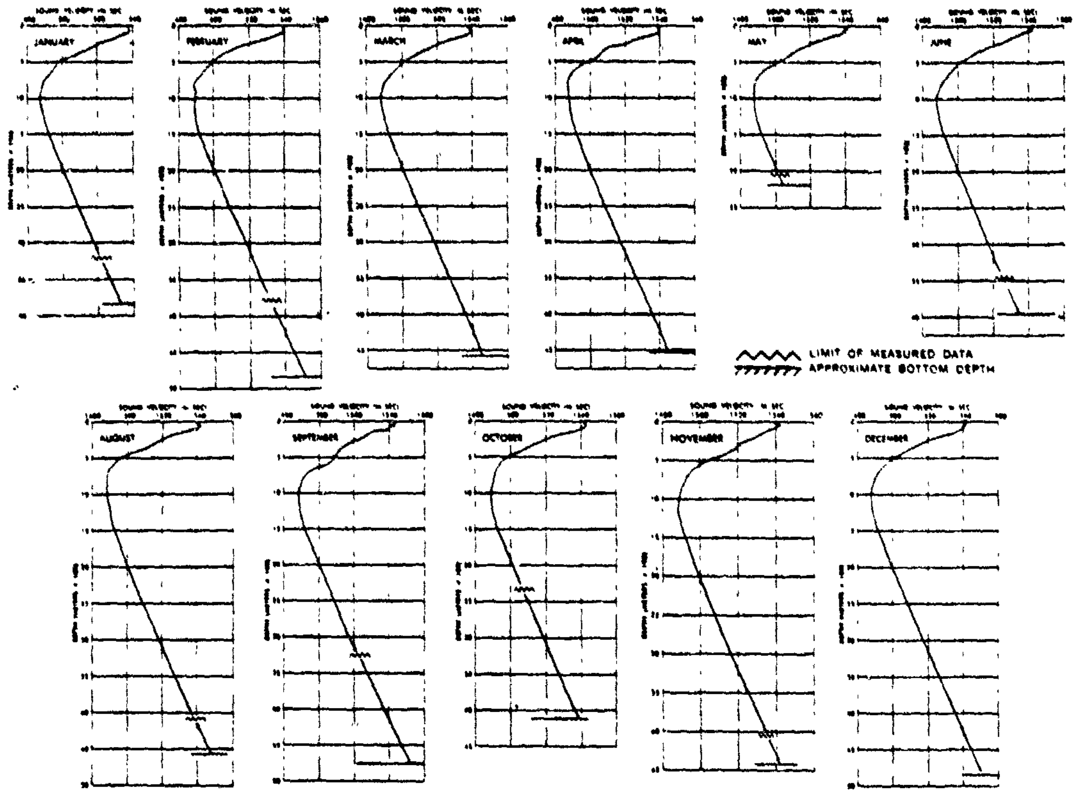

Figure 2-30. (U) Sound Speed Profiles in the North Venezuelan Basin (U)

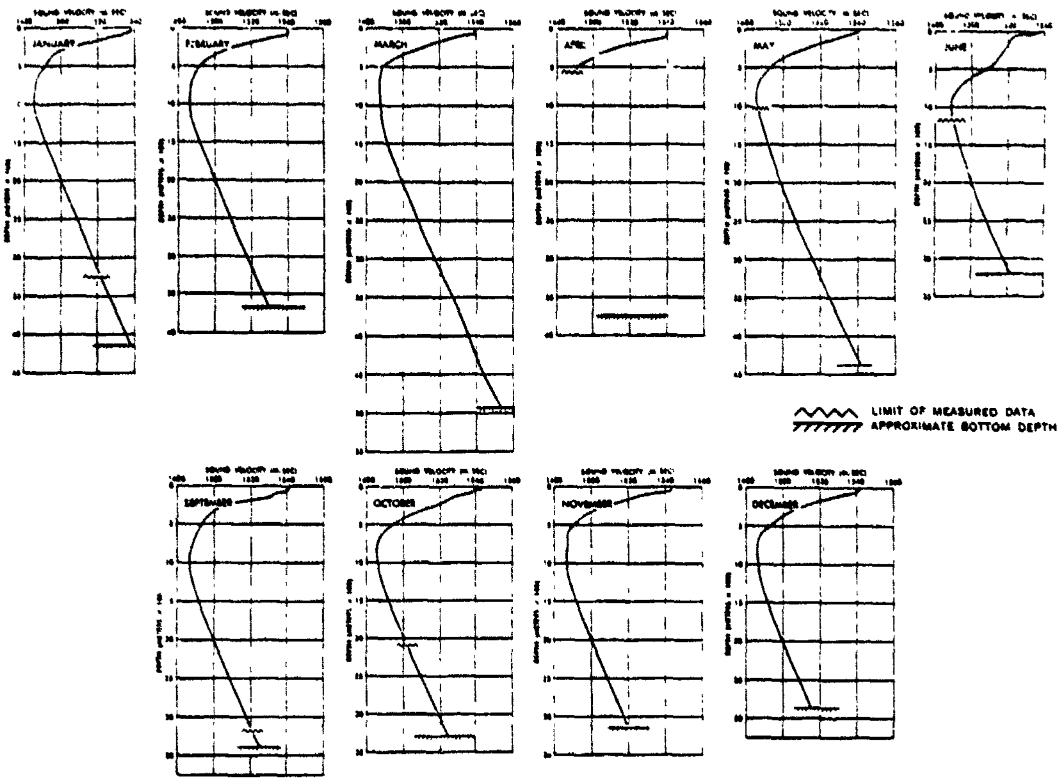

Figure 2-31. (U) Sound Speed Profiles in the South Venezuelan Basin (U)

(U)

which there is a depth excess. The Venezuelan Basin region is divided in the summer into the Southern Venezuelan Basin and the Muertos Trench with the area between being bottom-limited.

2.5.2 (U) Chart Availability (U)

(U) Charts of critical depth in the Gulf of Mexico and Caribbean Sea are available for both the summer and winter seasons in the Environmental-Acoustics Atlas of the Caribbean Sea and Gulf of Mexico (NOO, 1972). These are believed to be the most current critical depth charts of the region (Bucca, Paul, Personal Communication).

2.6 (U) <u>Bottom Loss/Structure</u> (U)

C. Spofford

Science Applications, Inc.

2.6.1 (U) Available Data (U)

(U) Available low frequency bottom loss data in the Gulf of Mexico and Northern Caribbean are quite sparse. As part of its bottom loss survey effort, the Naval Air Development Center (NADC) acquired a set of measurements in the area in 1971 and 1974.[1] The locations of the seven measurements within the area of interest are shown in Figure 2-32. Unfortunately, five of the data sets (indicated by O's in Figure 2-32) were contaminated by irrecoverable buoy calibration errors. The locations of the two remaining valid measurements are plotted as asterisks (*).

(U) The other potential source of bottom loss is the NAVOCEANO (MGS) Surveys[2]. Many stations were taken in the area; however, none was processed for frequencies below 500 Hz. No other direct measurements of bottom loss are known to the author at this time.

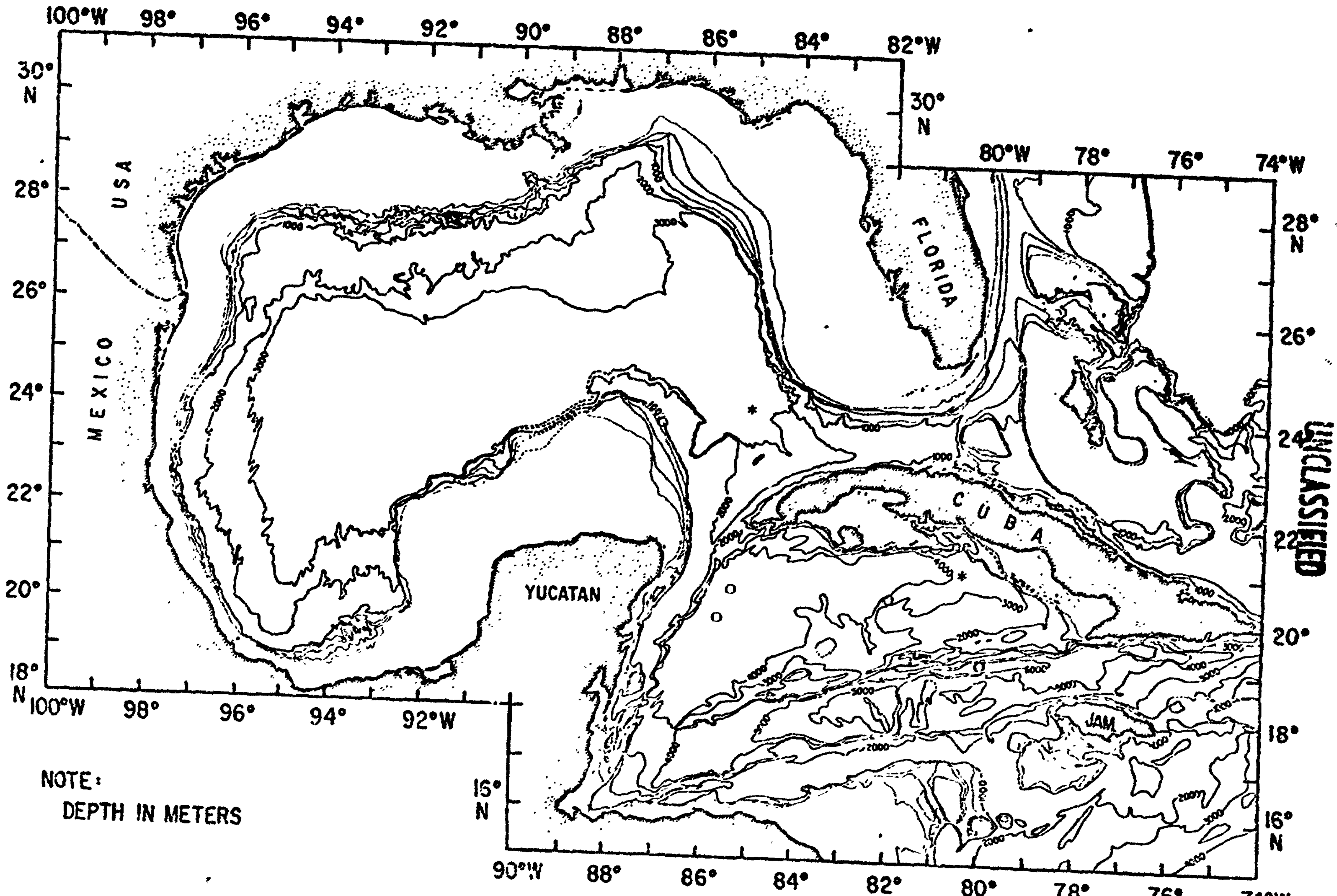

Figure 2-32. (U) Location of NADC Bottom-Loss Measurements (U)

* Valid Data   o Calibration Errors (Not Usable)

(U) An indirect source of bottom reflectivity data is long-range propagation loss measurements. In a bottom-limited area such as the Gulf, these data could be used to infer the loss at the grazing angle on the bottom corresponding to the zero-degree ray at the source.

2.6.2 (U) Geophysical Models (U)

(U) Based on an analysis of the NADC stations, the major basins in the area are covered by quite thick sediments of relatively low attenuation. Gradients in the sediments appear to range from $\sim$0.6 sec^{-1} in the Gulf and the Western end of the Yucatan/Cayman Basins to $\sim$1.2 sec^{-1} in the Eastern end of the Yucatan Basin. The volume attenuation within the sediments appears to be approximately 0.01 dB/m/kHz in the Yucatan/Cayman area and somewhat higher in the Gulf of Mexico.

(U) At the water-sediment interface the sound speed exhibits at most a slight decrease in the Yucatan/Cayman area but a substantial decrease ($\sim$20-30 m/sec) in the Gulf. The density of the sediment at the interface is approximately 2.1 gm/cm^3. The sediments are generally thick enough that basement returns are not seem. In the Eastern Gulf, the sediments appear to be $\sim$2 km thick and a weak basement return is observed at low frequencies.

2.6.3 (U) Bottom Loss Predictions (U)

(U) Based on these analyses, the bottom loss in the deep areas has been categorized by three sets of curves, and additional sets have been defined for the slope and shallow-water regions. Figure 2-33 indicates the geographic assignment of the 5 types (A through E). Figures 2-34 through 2-38 display the curves for frequencies of 25, 50, 100, 200 and 400 Hz. Below each figure the parameters of the curves are tabulated to assist in their incorporation into computer programs. The parameters vary linearly in frequency and angle between the specified values.

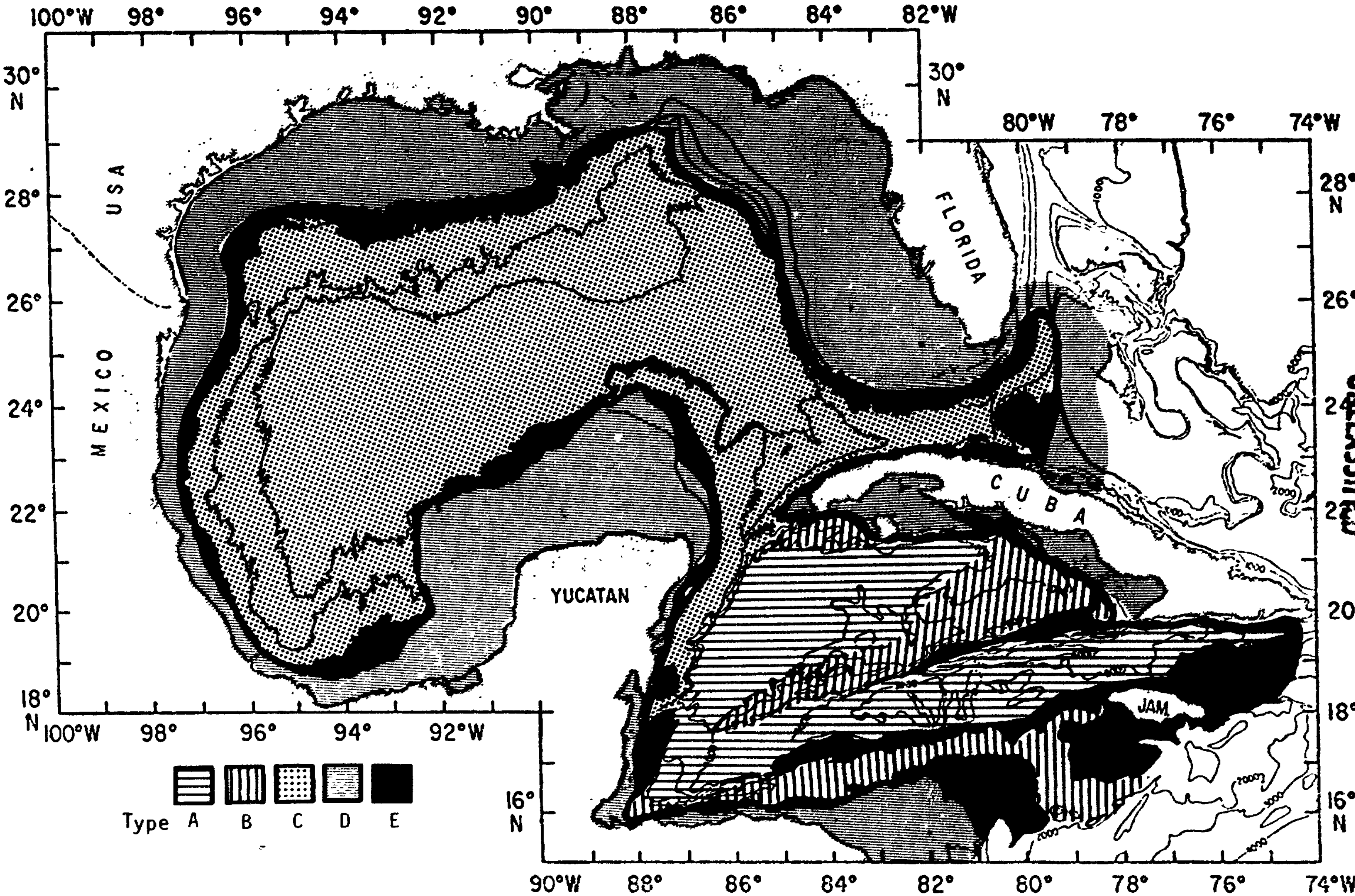

Figure 2-33. (U) Geographic Assignment of Bottom Types

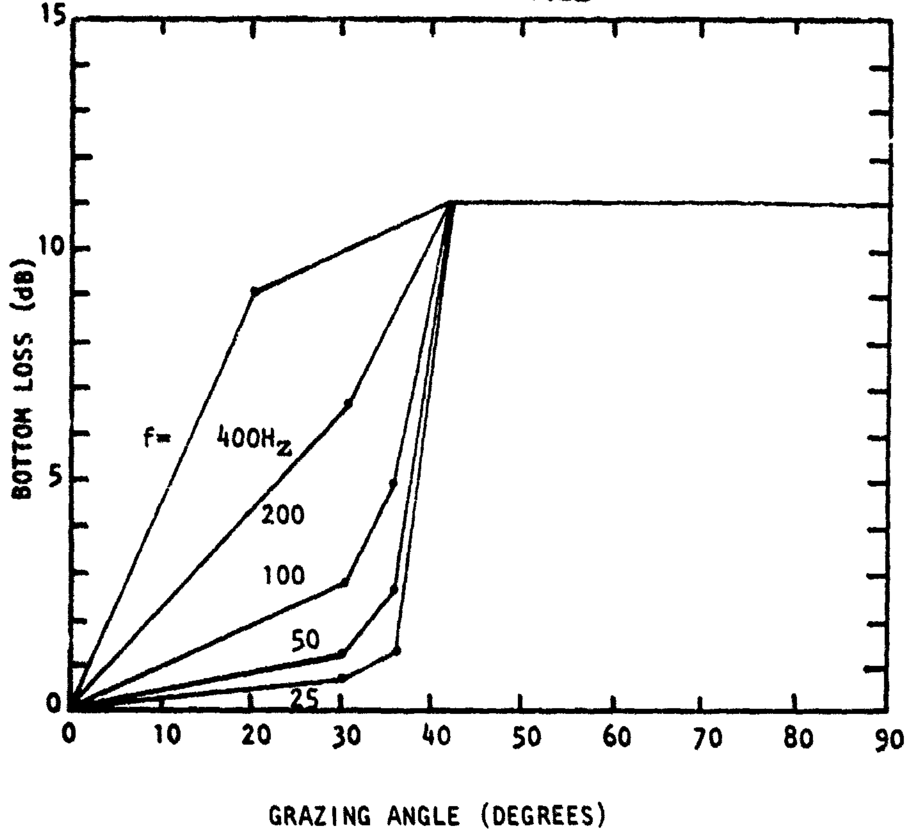

Figure 2-34. (U) Bottom-Loss Curves for Type A (U)

Freq. (Hz)	BL (0^o)	θ_1	BL(θ_1)	θ_2	BL(θ_2)	θ_3	BL($\theta>\theta_3$)
25	0.0	30	.75	35	1.25	40	11.0
50	0.0	30	1.5	35	2.5	40	11.0
100	0.0	30	3.0	35	5.0	40	11.0
200	0.0	30	7.0	--	---	40	11.0
400	0.0	20	9.0	--	---	40	11.0

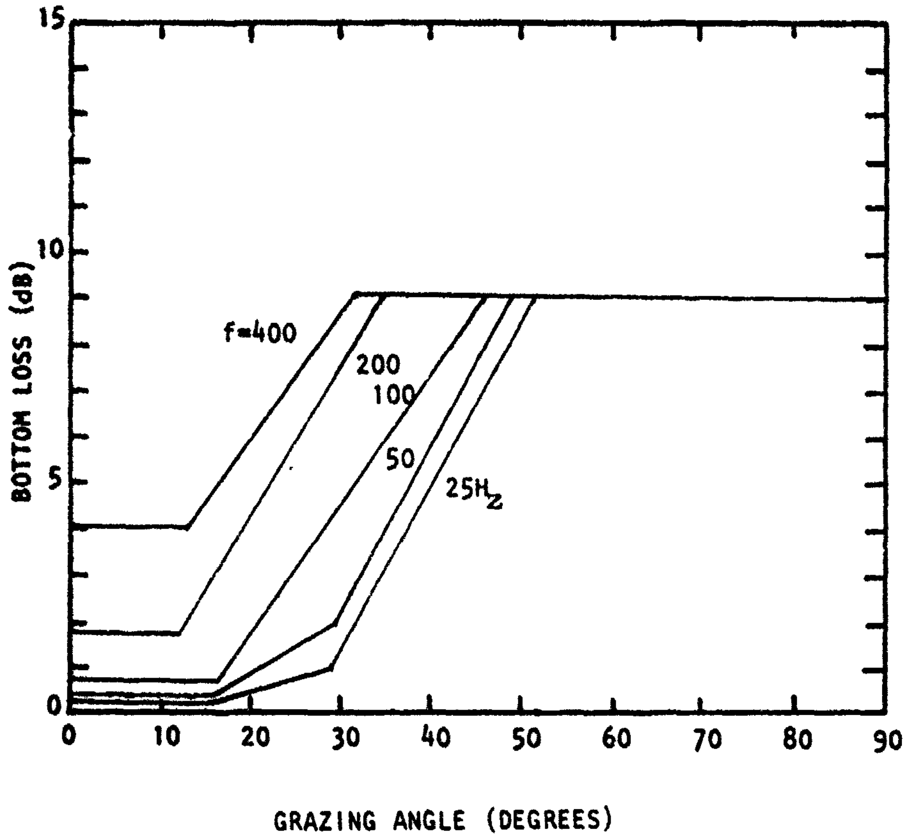

Figure 2-35. (U) Bottom-Loss Curves for Type B (U)

Freq.(Hz)	$BL(\theta<\theta_1)$	θ_1	θ_2	$BL(\theta_2)$	θ_3	$BL(\theta>\theta_3)$
25	.2	15	28	1.0	50	9.0
50	.4	15	28	2.0	47	9.0
100	.8	15	--	---	45	9.0
200	1.8	12	--	---	33	9.0
400	4.0	12	--	---	30	9.0

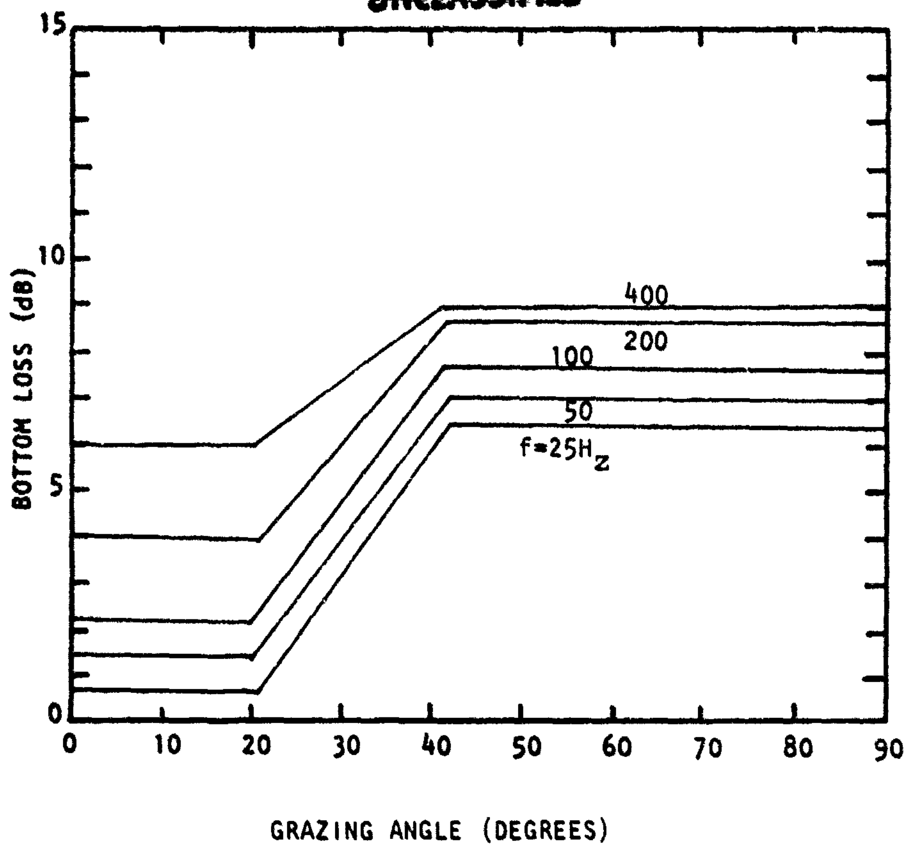

Figure 2-36. (U) Bottom-Loss Curves for Type C (U)

Freq. (Hz)	BL($\theta < 20^{\circ}$)	BL($\theta > 40^{\circ}$)
25	.8	6.5
50	1.5	7.0
100	2.2	7.5
200	4.0	8.5
400	6.0	9.0

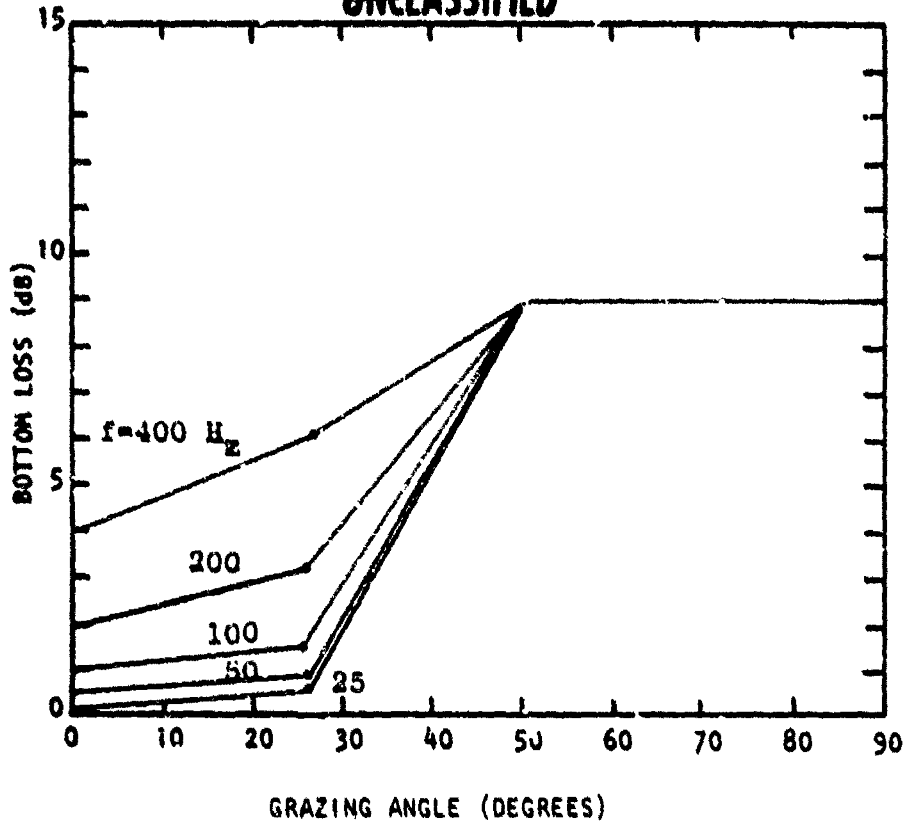

Figure 2-37. (U) Bottom-Loss Curves for Type D (U)

Freq. (Hz)	BL(θ)	BL(25°)	BL(θ>50°)
25	.25	.375	10.0
50	.5	.75	10.0
100	1	1.5	10.0
200	2	3	10.0
400	4	6	10.0

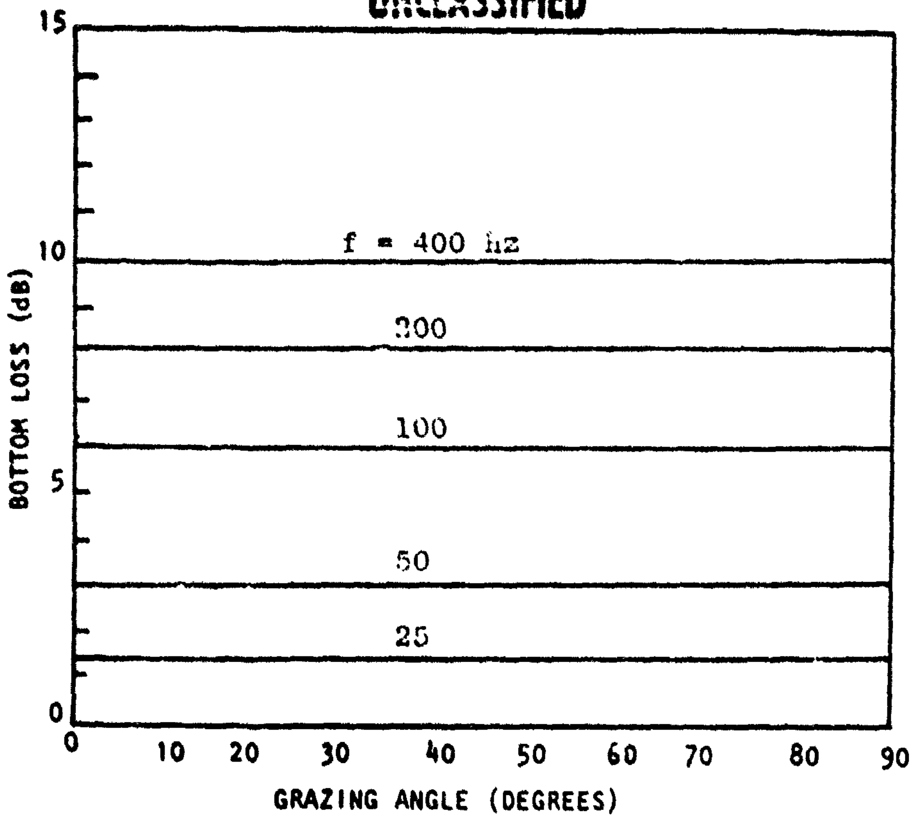

Figure 2-38. (U) Bottom-Loss Curves for Type E (U)

Freq. (Hz)	BL ($0^0 \leq \theta \leq 90^0$)
25	1.5
50	3.0
100	6.0
200	8.0
400	10.0

2.6.4 (U) Confidence Estimates (U)

(U) The curves presented represent the best estimates by SAI based on the sources of information discussed above. The key uncertainties in this analysis are:

(1) For thick-sediment (deep) areas the geographic extrapolation of types A, B, and C from their measurement sites is uncertain. Changes in sediment type (and hence attenuation) or gradient may significantly alter the reflectivity. The Western Gulf area represents the greater extrapolation and hence the maximum uncertainty.

(2) For shallow-water areas the loss curves (D) represent an extrapolation of high-frequency data and may indicate an optimistically good reflector at the lower frequencies. Even at 25 Hz the loss of 1/4 to 1/2 dB per bounce at shallow angles should rapidly attenuate levels from sources very far into the shallow water.

(3) The slope curves (E) may be the most uncertain. The form and values selected correspond to thin-sediment data acquired in other areas where signals reflect off exposed basement material and appear to lose energy largely through scattering mechanisms. While sediments are extremely thick even in the slope regions of the Gulf, the relief may be rough enough to give similar scattering losses. The low-angle losses given by curve E may be considerably less at all frequencies on the slopes of the Gulf.

2.7 (U) Pre-Exercise Estimates of Bottom Interaction in The Gulf of Mexico and The Caribbean Sea (U)

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2.7.1 (U) Introduction (U)

(U) During FY 79, the Long Range Acoustic Propagation Project (LRAPP) will conduct a series of exercises in the Gulf of Mexico and Caribbean Sea (GULF/CARIB). The most important factor determining the characteristics

of acoustic propagation at long range in that region will be the nature of the interaction of sound fields with the ocean bottom there. The purpose of this memorandum is to briefly survey the bottom interaction problems, to provide estimates of the range of bottom loss to be expected, and to point out the quantities for which measurements need to be made during the exercise.

(U) Figure 2-39 shows the regions which will be considered here. Estimates of bottom loss will be given for the shaded regions. In general, long range propagation will occur only across these deep basin regions, so they should be of primary interest. However, because of the concentration of noise sources there, the nature of propagation across the Texas-Louisiana Shelf and Slope--which must be regarded as unknown prior to the exercise -- may be of equal importance in determining system performance in the Gulf.

(U) Propagation in the Gulf is entirely bottom limited, and there is a minimum bottom grazing angle. Using sound speed profiles from Reference 3 for the month of May, one may calculate that beyond a few kilometers from the source, the field from a 100 m deep source will reflect from the bottom at angles of approximately 8 deg or greater in the lower Mississippi Fan and 6 deg or greater in the Western Gulf.

(U) For practical purposes, propagation in the Yucatan Basin also is bottom limited. The sound speed profiles of Reference 3 show that, in May, there is less than 100 m of depth excess in the Yucatan Basin.

2.7.2 (U) Parameters of Bottom Interaction (U)

(U) The most familiar characterization of bottom interaction is the quantity known as "bottom loss". In an ideal theoretical sense, bottom

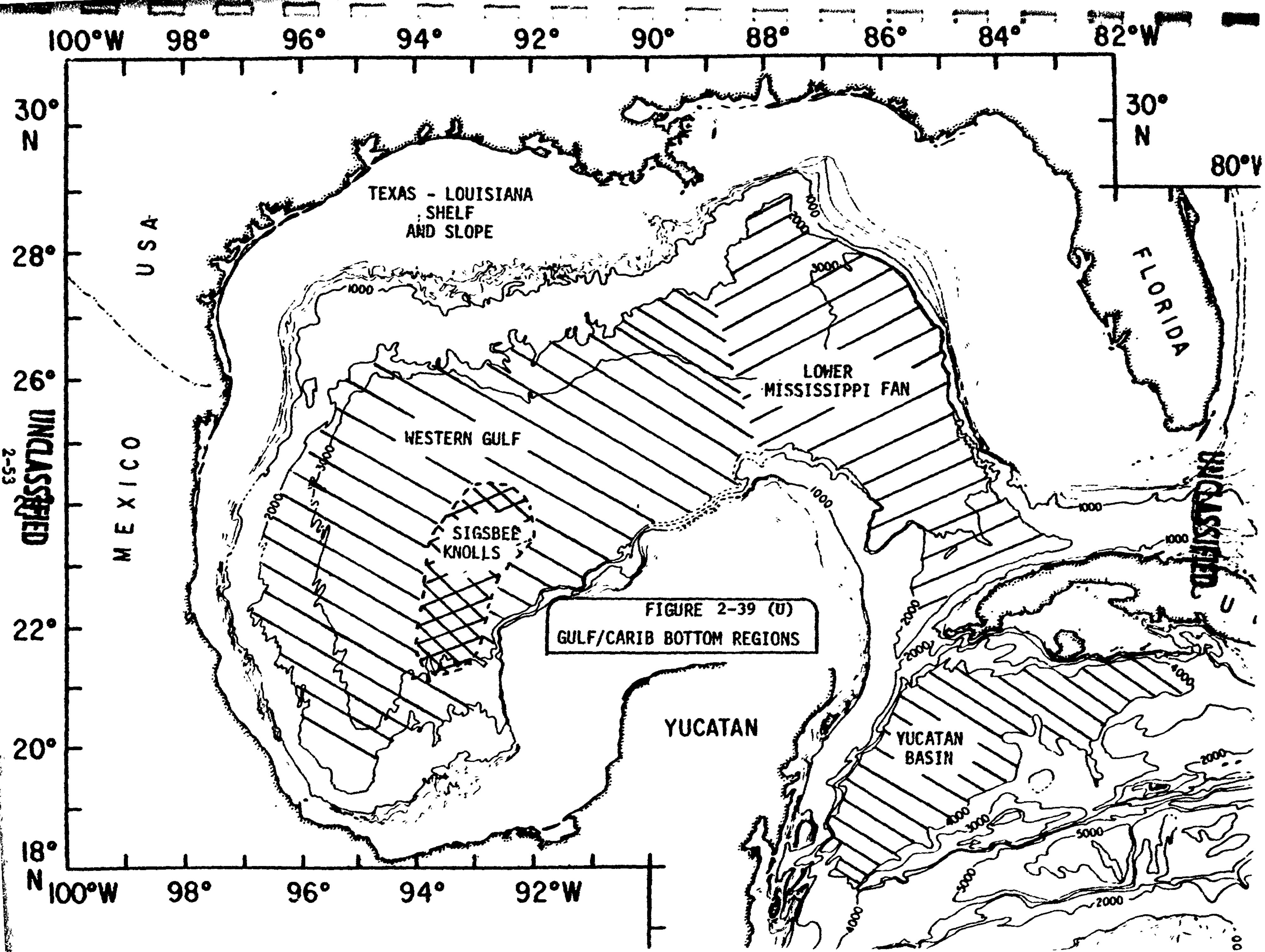


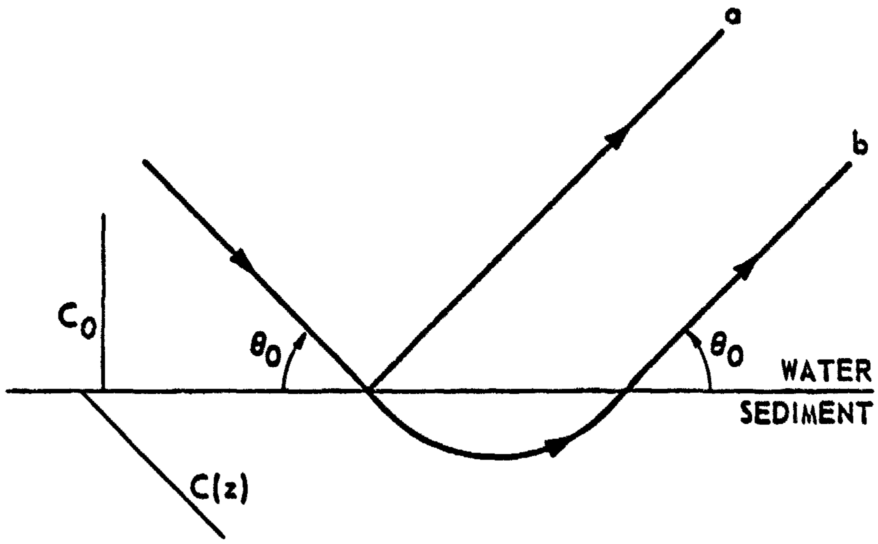
FIGURE 2-39 (U)
GULF/CARIB BOTTOM REGIONS

(U)

loss is the amplitude of the plane wave reflection coefficient (in decibels) for waves incident on the bottom. In practice, experimental measurement of bottom loss requires considerable careful calculations in addition to careful signal measurements (References 4 and 5). In fact, recent work has shown that, in many ocean areas, the simple bottom loss concept breaks down at low frequencies (References 6 and 7). This is because, in areas such as the GULF/CARIB, which have thick sediment layers, low frequency energy actually refracts at depth in the bottom rather than reflects from the bottom interface. However, for purposes of general overviews, considerations of estimated bottom loss are useful. That is, if bottom loss at some frequency were expected to be low (less than 1.0 dB/reflection, say) over an appreciable bottom grazing angle interval, then one would expect good propagation, or, if the bottom loss were expected to be high (greater than 2.0 dB/reflection), then long range propagation will not be good.

(U) For this memorandum, bottom loss values have been calculated using "geoacoustic models" of the ocean bottom in the regions of Figure 2-39. The geoacoustic models are discussed in References 8 through 14, and computations of bottom reflectivity in References 15 through 17 and references therein. For the present purposes, the picture of bottom interaction given by Figure 2-40 is adequate.

(U) Figure 2-40 shows the incident field separated into two parts as it reaches the bottom. One part is specularly reflected at the interface, while the second part penetrates, refracts, and then returns to the water. In practice, these two components arrive within approximately 100 msec or less of each other (for low grazing angles) and appear to constitute a single "reflected arrival". The level of the reflected arrival (and hence the bottom loss) is determined from the combination of the two parts.



PATH a – REFLECTED AT BOTTOM INTERFACE
PATH b – REFRACTED THROUGH BOTTOM SEDIMENT

FIGURE 2-40 (U)
SEPARATE RAY MODEL OF BOTTOM INTERACTION (U)

(U) The level of the specularly reflected component is determined almost entirely by the density contrast at the ocean bottom, while the level of the refracted component is determined by the path length of the refracting ray in the bottom and the attenuation along the path. It has been found that, in basin areas similar to those of Figure 2-39, at frequencies below 200 Hz and grazing angles below 30 deg, practically all of the "reflected" signal is due to the refracted path.

(U) The raypath of the refracting ray is determined by the same thing which determines the raypath in the water column--the compressional wave velocity profile. The attenuation along the path is determined by the function of attenuation coefficient vs depth, or attenuation profile. Therefore, bottom loss will be determined by these two profiles.

(U) Estimates of sound velocity profiles for the shaded areas of Figure 2-39 have been provided from J. Matthews (Reference 18). These were obtained from analysis of core samples and sonobuoy profiling records. These profiles are shown in Figure 2-41 and tabulated in Table 2-1. Except for the Sigsbee Knolls, these profiles are similar to those estimated for other basin regions, though the near-surface gradients are somewhat larger than for other regions (References 8, 9). The Sigsbee Knolls profiles are very different, with gradients near the surface of 0.27 sec^{-1} rather than a nominal 1.5 sec^{-1} for the other regions. This causes the bottom loss predicted for the Knolls regions to be much larger, as discussed below.

(U) Estimates of attenuation profiles in the exercise area are not available. In fact, as far as bottom interaction is concerned, the most important result of the exercise will be measurements of that currently unknown quantity. For that reason, it is important that bottom interaction samples be obtained in each of the different regions.

(U) For purposes of pre-exercise assessment, attenuation profiles obtained during recent exercises (References 6, 19) were used. Figure 2-42 shows attenuation profiles representative of ocean basin areas

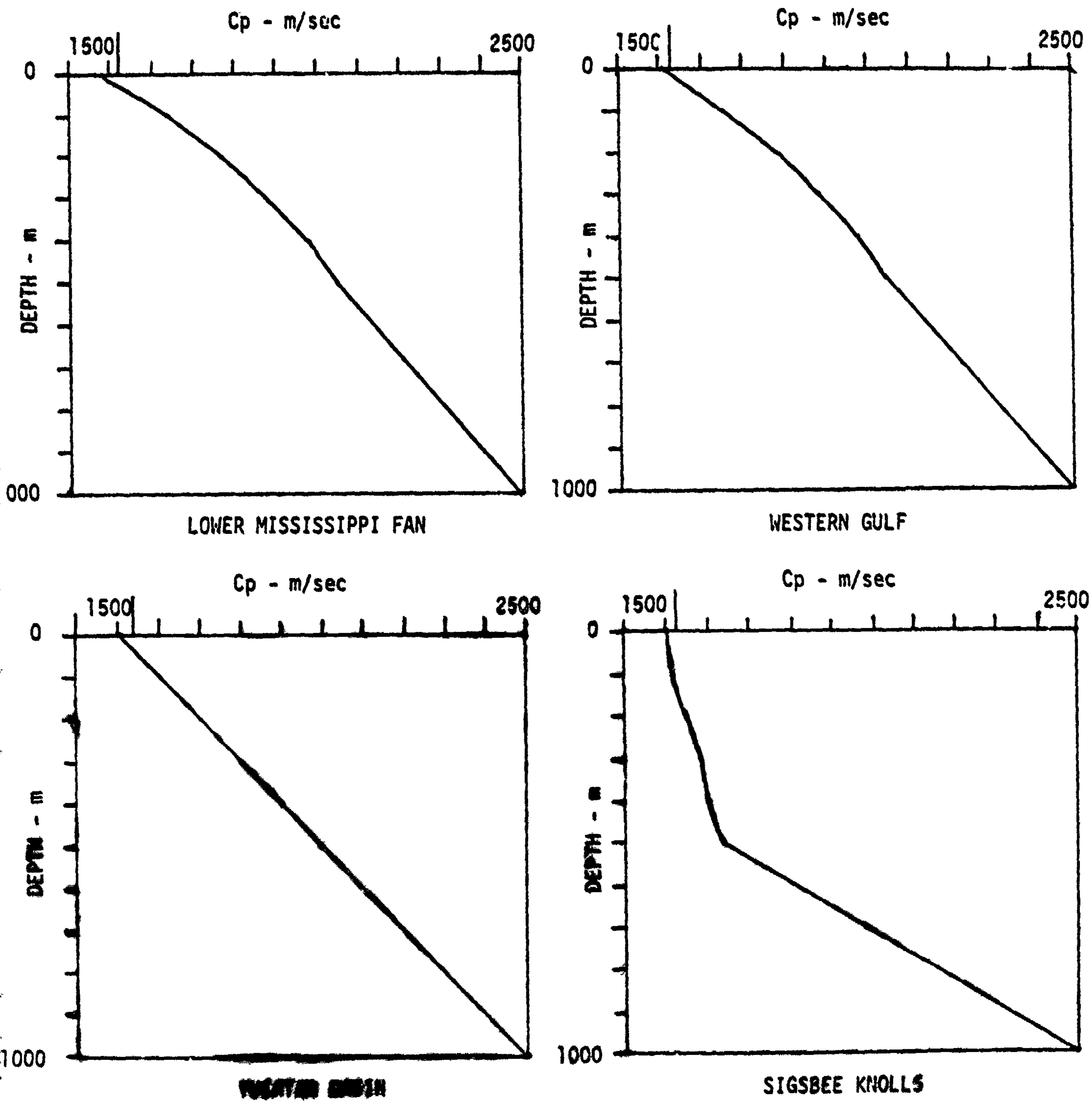


FIGURE 2-41 (U)

GULF/CARIB SUBBOTTOM
COMPRESSIONAL WAVE VELOCITY PROFILES (U)

TABLE 2-1
SUBBOTTOM COMPRESSIONAL WAVE VELOCITY PROFILES FOR GULF/CARIB

depth m	Lower Miss. Fan	Yucatan Basin	Western Gulf	Sigsbee Knolls
0-	1520 m/sec	1540 m/sec	1530 m/sec	1530 m/sec
0+	1482 m/sec	1511 m/sec	1504 m/sec	1501 m/sec
100	1636 m/sec	1609 m/sec	1652 m/sec	1528 m/sec
200	1770 m/sec	1706 m/sec	1780 m/sec	1555 m/sec
300	1885 m/sec	1804 m/sec	1888 m/sec	1582 m/sec
400	1979 m/sec	1902 m/sec	1976 m/sec	1609 m/sec
500	2052 m/sec	2000 m/sec	2044 m/sec	1636 m/sec
1000	2500 m/sec	2500 m/sec	2500 m/sec	2500 m/sec

Notes:

1. Values derived following Ref. 16
2. 0- means bottom water; 0+ means sediment surface
3. Sediment thickness arbitrarily set to 1 km, with velocity 2500 m/sec there
4. Anamolous structure in Sigsbee Knolls arbitarily set to 500 m thickness
5. Sediment Density of 1.51 used for bottom loss calculations

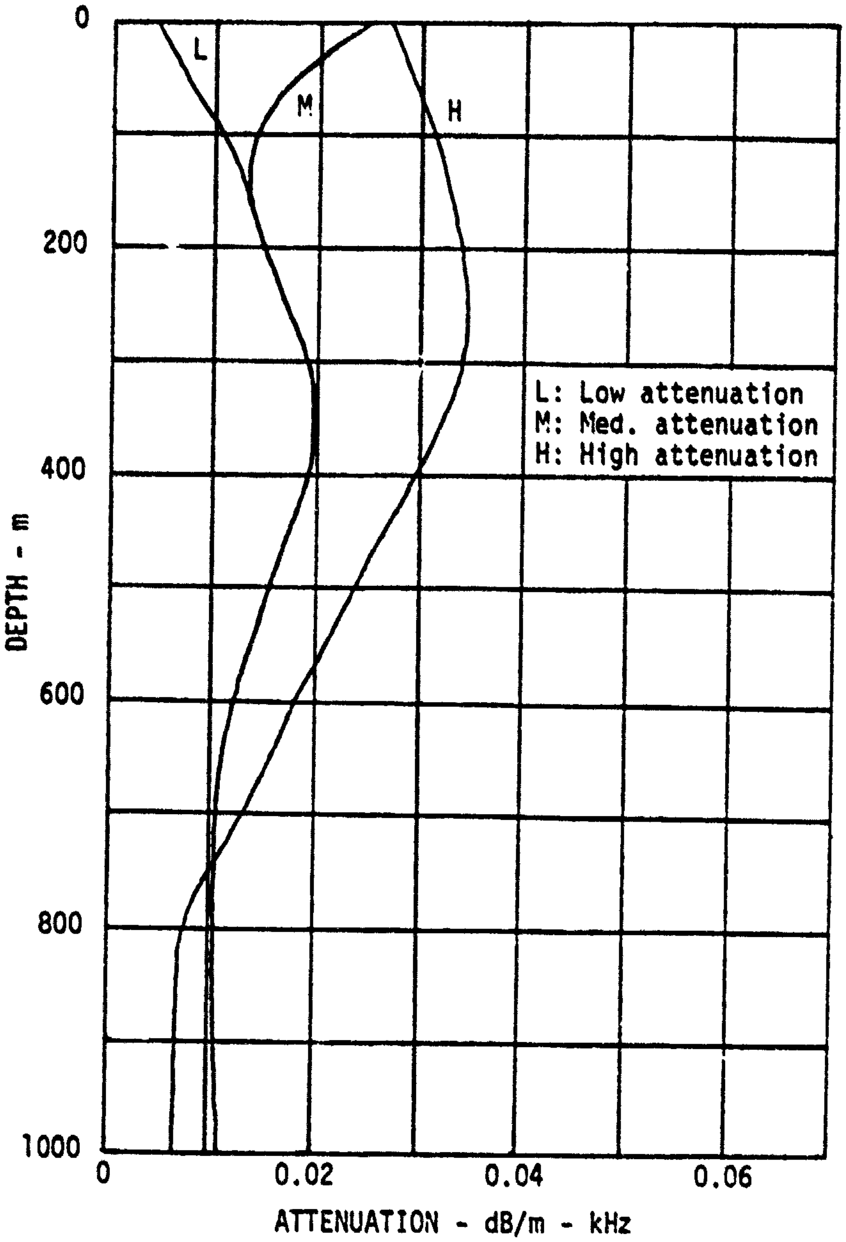


FIGURE 2-42 (U)

REPRESENTATIVE ATTENUATION PROFILES
MEASURED IN AREAS SIMILAR TO GULF/CARIB BASINS (U)

(U)

similar to those of Figure 2-39. In the GULF/CARIB basins, the attenuation profiles probably will lie among these, but that can be determined only by measurements.

(U) Figure 2-42 shows a "low", "medium", and a "high" attenuation profile. It should be noted that all of these attenuations are significantly less than estimates based upon older measurements (References 10, 11, 20).

(U) In the bottom loss calculations, the sediment portions of the geoacoustic models were assumed to be 1000 m thick. This is somewhat arbitrary, as better estimates have not been obtained. However, these sediments are at least several hundred meters thick, so that calculations using the actual sediment thickness would differ from those using the 1000 m thickness below only at grazing angles above approximately 40 deg. For estimation of long range propagation almost identical results would be obtained.

2.7.3 (U) Bottom Loss Estimates (U)

(U) Bottom loss estimtes for the areas other than the Sigsbee Knolls are shown in Figures 2-43 through 2-45. These show bottom loss calculations in 1/3 octave bands at 25, 50, 100, and 200 Hz for each of the three attenuation profiles of Figure 2-42. There is some difference between the bottom loss predicted for different regions with the same attenuation type. However, there is much greater variation among predictions using different attenuation types in the same region.

(U) To compare these results in more detail, let us adopt the rule that "good" long range propagation in a bottom limited basin can occur when there is a grazing angle interval with 1 dB or less bottom loss. Then, we can compare propagation in the regions under the assumption that the same attenuation will be found in each. More complicated intercomparisons are possible.

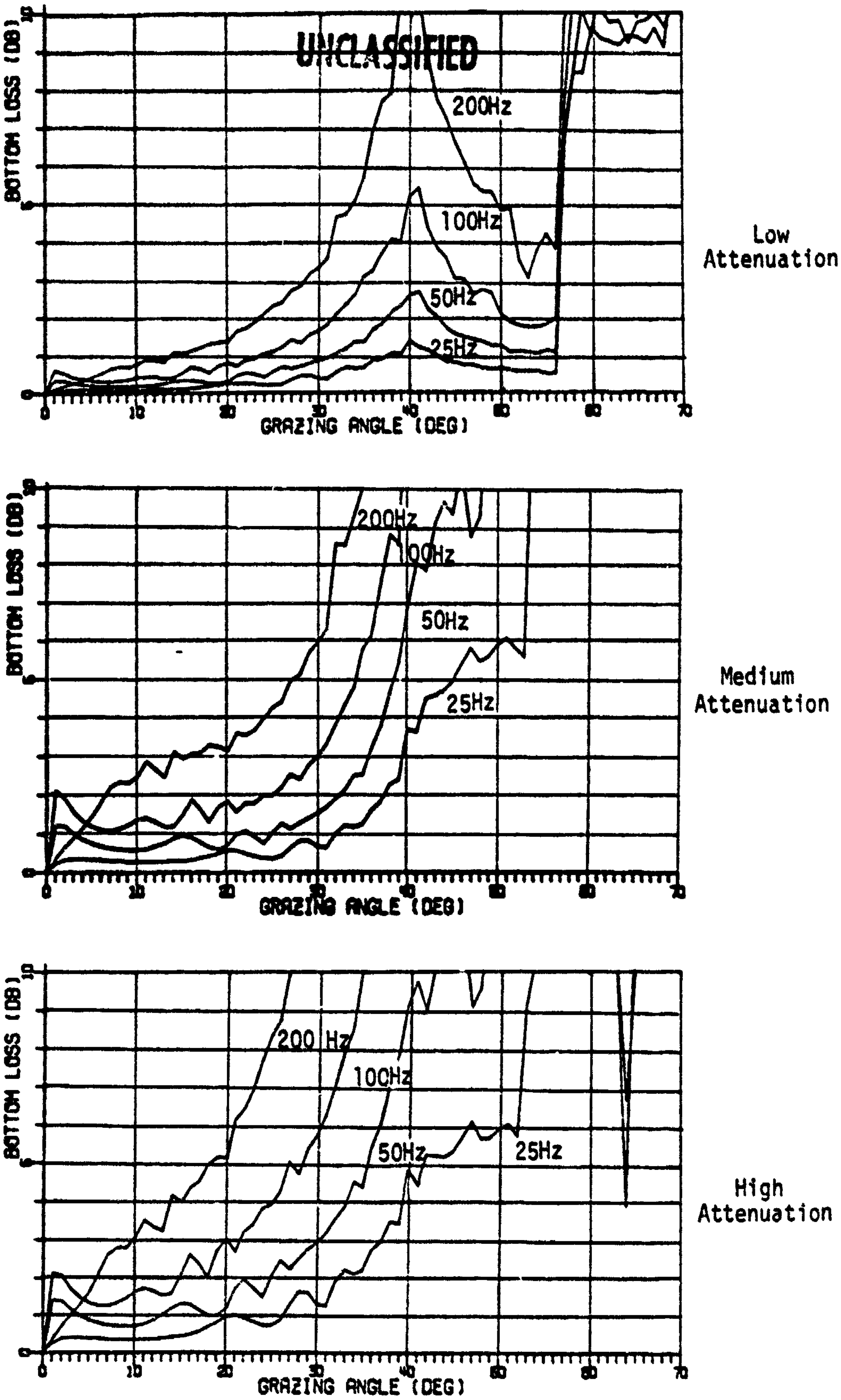
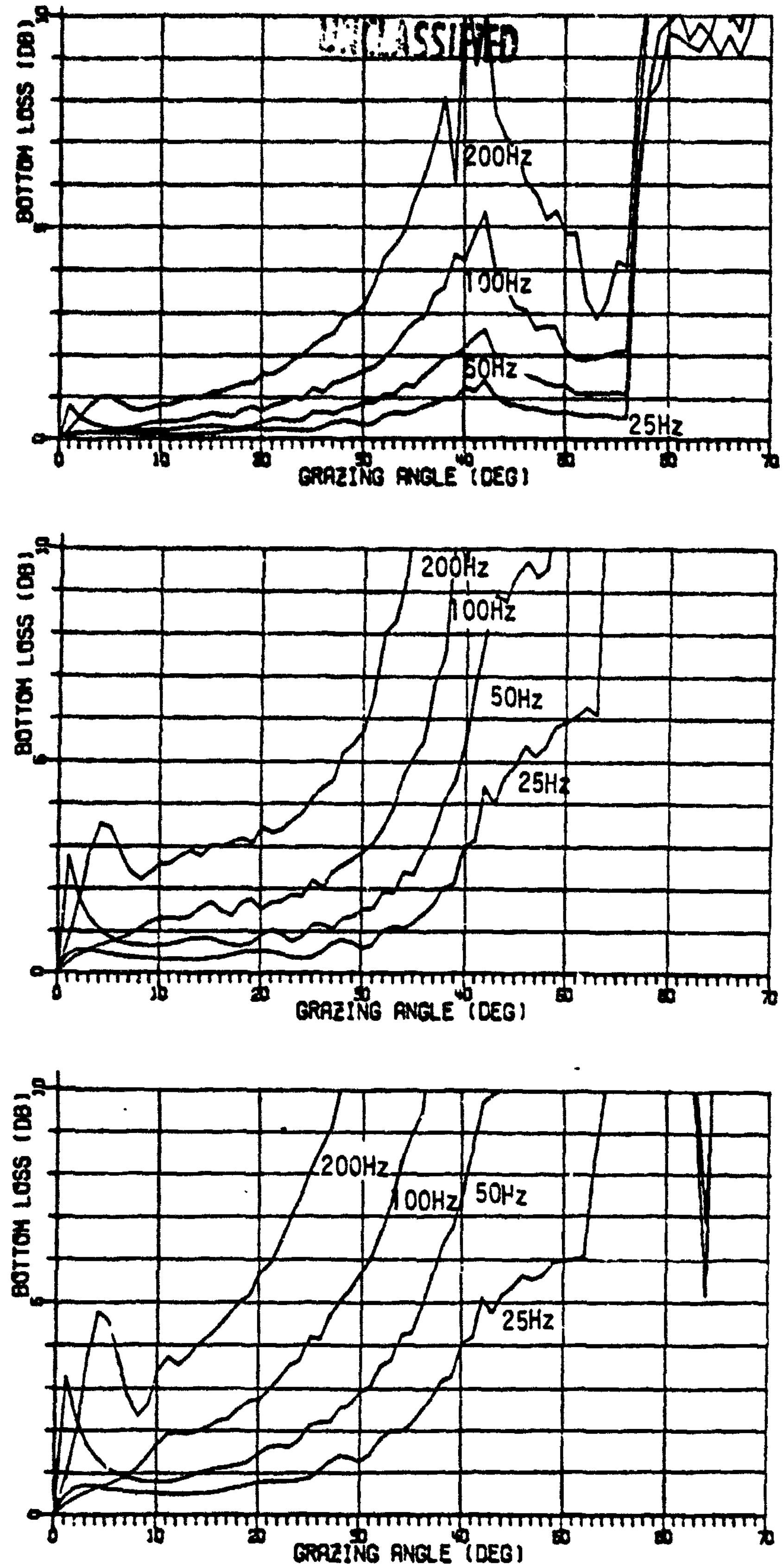


FIGURE 2-43 (U)

BOTTOM LOSS ESTIMATES FOR
WESTERN GULF OF MEXICO
(OUTSIDE OF SIGSBEE KNOLLS) (U)



Low Attenuation

Medium Attenuation

High Attenuation

FIGURE 2-44 (U)

BOTTOM LOSS ESTIMATES FOR MISSISSIPPI FAN (U)

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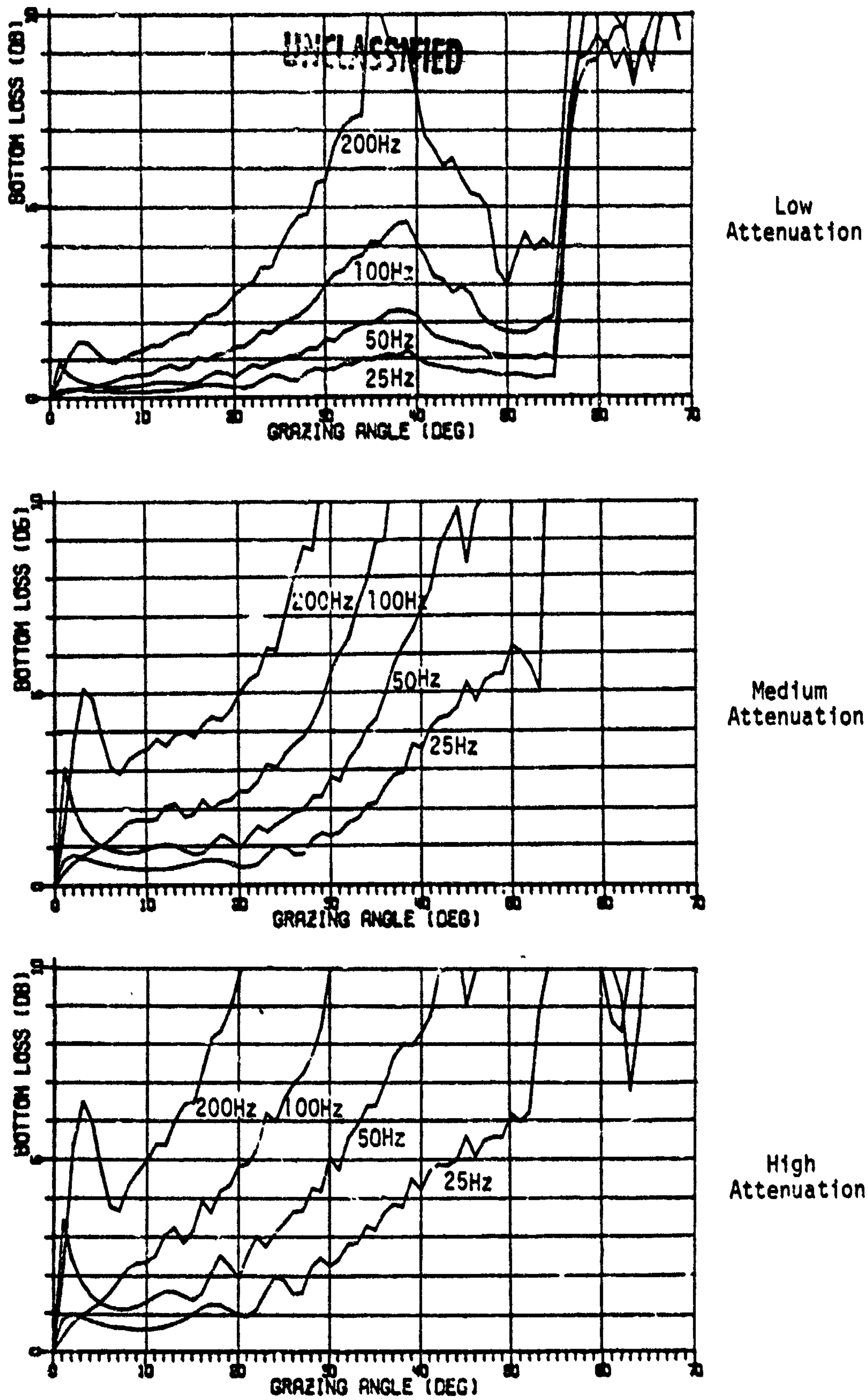

FIGURE 2-45 (U)

BOTTOM LOSS ESTIMATES FOR
YUCATAN BASIN (U)

(U) If either the high or medium attenuation profiles occur everywhere, then good propagation will occur (under the above rule) at 25 and 50 Hz in the Western Gulf and Mississippi Fan, but probably only at 25 Hz in the Yucatan Basin. In contrast, if the low attenuation profile occurs everywhere, then good propagation will be found in all areas at 200 Hz and below, with the possible exception of the Yucatan Basin at 200 Hz.

(U) The subbottom velocity profiles for the Sigsbee Knolls were distinctly different than the others of Figure 2-41. The bottom loss estimates shown in Figure 2-46 are also very different than those for the other basin regions, showing much more bottom loss than the others. This is because the raypath lengths are much greater in that region of small gradient in the velocity profile.

(U) It is difficult to assign a meaning to the bottom loss prediction of Figure 2-46. Figure 2-39 shows the Sigsbee Knoll region as a solid region. However, the anomalous bottom properties occur in knolls (salt domes or protrusions) which are nominally 4 nm in diameter and 10 to 30 nm apart (Reference 21). The bottom loss in the spaces between knolls probably is similar to that of the rest of the Western Gulf. Thus, the Sigsbee Knoll regions probably should be thought of as a region with high loss "spots" scattered on a more conventional bottom.

(U) On the basis of these bottom loss calculations for the Sigsbee Knolls, one recommendation for the Gulf/Caribbean experiments can be made. When bottom loss measurements are made, the PAR or ACODAC recording systems should, if possible, be located slightly outside the perimeter of the Knoll region. This will allow samples of bottom interaction in the Western Gulf and the Sigsbee Knoll regions separately. The receiver should not be in the Knoll regions, for then many measurements would be sampling interactions in what should be very different regions.

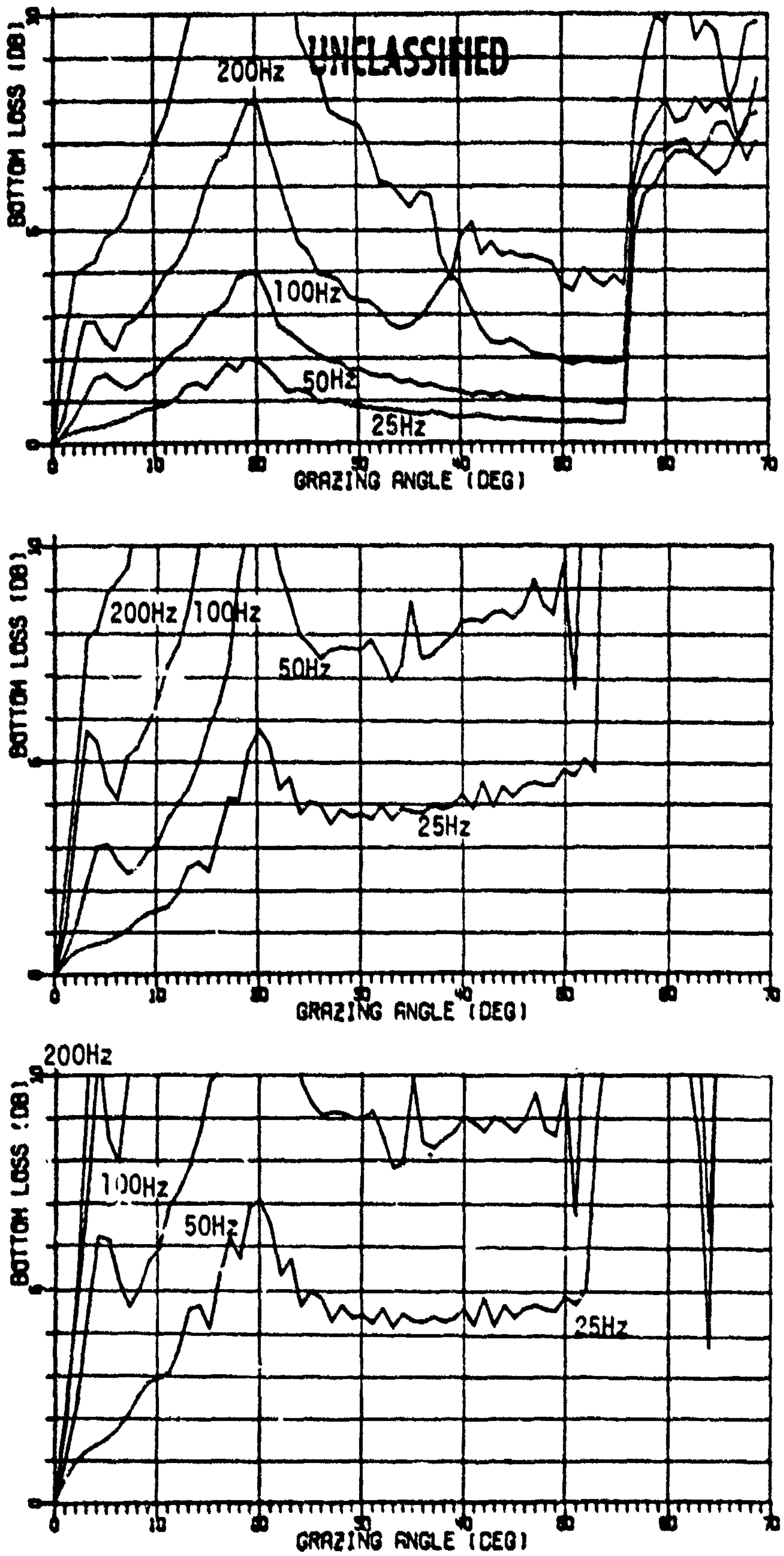

FIGURE 2-46 (U)

BOTTOM LOSS ESTIMATES FOR SIGSBEE KNOLLS (U)

2.7.4 (U) Summary (U)

(U) Acoustic propagation in the GULF/CARIB will be determined by the acoustic properties of the ocean bottom there. Pre-exercise estimates of bottom loss indicate that, if subbottom attenuation profiles are similar to those measured in similar basin areas, good long-range propagation across the basin areas, except in the Sigsbee Knolls regions, should occur at frequencies of 50 Hz and below. If the attenuation turns out to be as low as the lowest values measured in similar areas, good propagation will occur at 200 Hz and below. In the Sigsbee Knolls, high bottom loss and poor acoustic propagation should be anticipated.

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3.0 (C) ACOUSTIC DATA SUMMARY (U)

3.1 (U) Propagation Loss (U)

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(U) Many possible sources of data for propagation loss in the Gulf of Mexico and the Caribbean Sea were investigated. Of these, only a few had data applicable to this preassessment. Each of these sources involved data collected during Naval exercises or using Naval assets.

3.1.1 (U) Propagation Loss Data Locations and Sources (U).

(U) Six sources of data were found. These were the Naval Ordnance Laboratory (NOL),[1,2,3] since renamed the Naval Surface Weapons Center/ White Oak Laboratory (NWSC/WOL)[4], Naval Oceanographic Office (NAVOCEANO)[6], and the KIWI[7,8] and CHURCH GABBRO[9,10] exercises. See Figure 3-1 for measurement locations.

(U) For the Caribbean the CHURCH GABBRO exercise has the best data available. The results from this exercise are primarily for the Cayman Trough. The data was collected by a Telemetry Acoustic Buoy System (TABS) and ACODACs. Both SUS and CW tows were used as sources.

(U) The KIWI exercise, WOL and NOL experiments have the best information for the Gulf of Mexico area.

(U) The KIWI exercise data has one run each in the Gulf of Mexico and the Caribbean. The Carribbean run extends from the Colombian Basin into the Venezuelan Basin. This data is not of much use since it is much farther south than our area of interest. The run in the Gulf of Mexico extends from the West Florida Shelf down into the Mexico Basin (see Figure 3-1). This covers roughly the same area as the ENE run proposed for the West Gulf experiment. Due to adverse weather conditions, much of the data obtained had an unacceptable signal to noise ratio; however, it was found that valid transmission loss data could be obtained for the limited frequency range 200-630 Hz. The receiving hydrophones were located from 800 to 8000 ft while 800 and 1500 ft SUS charges were deployed by aircraft

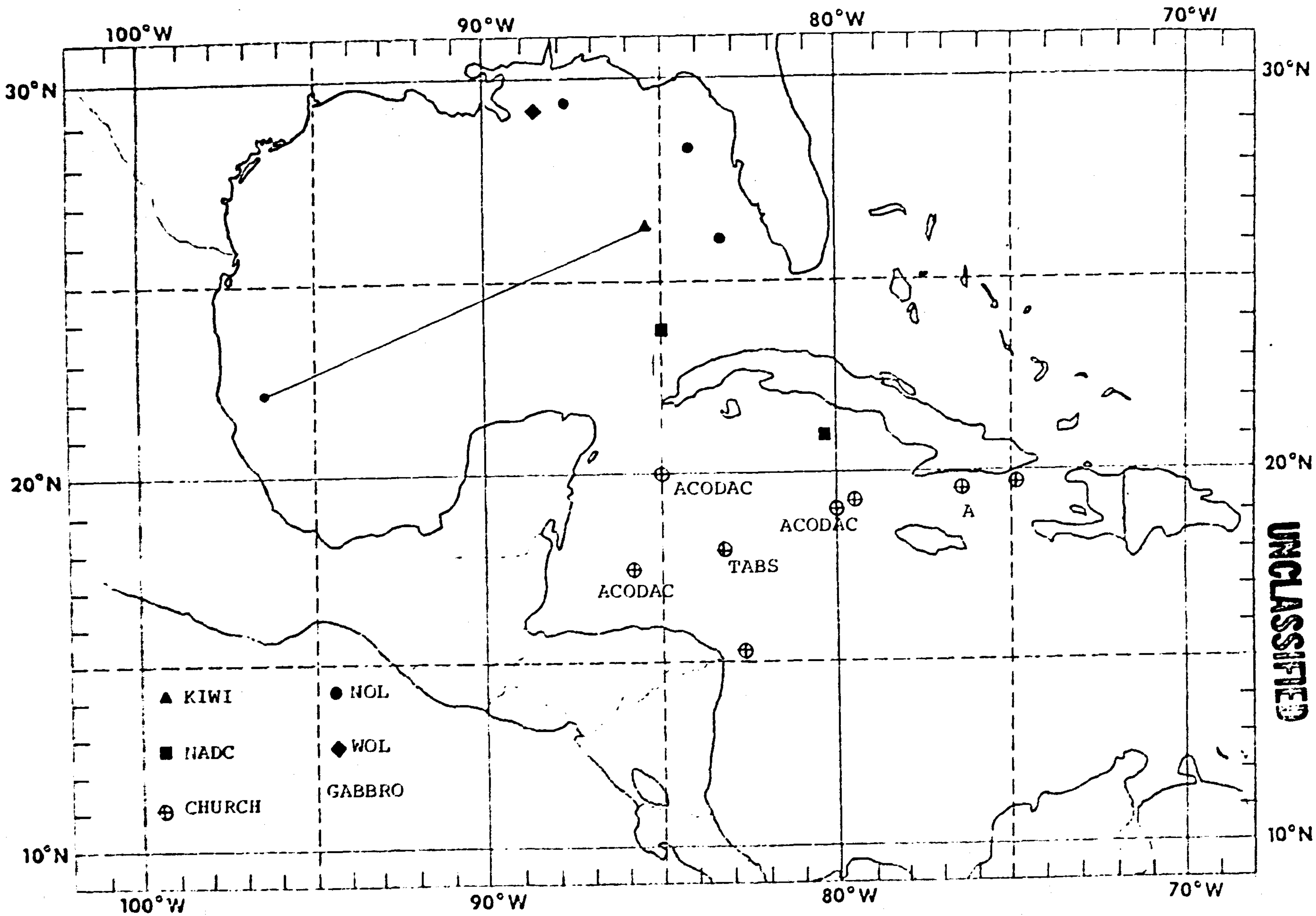

FIGURE 3-1 (U) Transmission Loss Measurement Sites (U)

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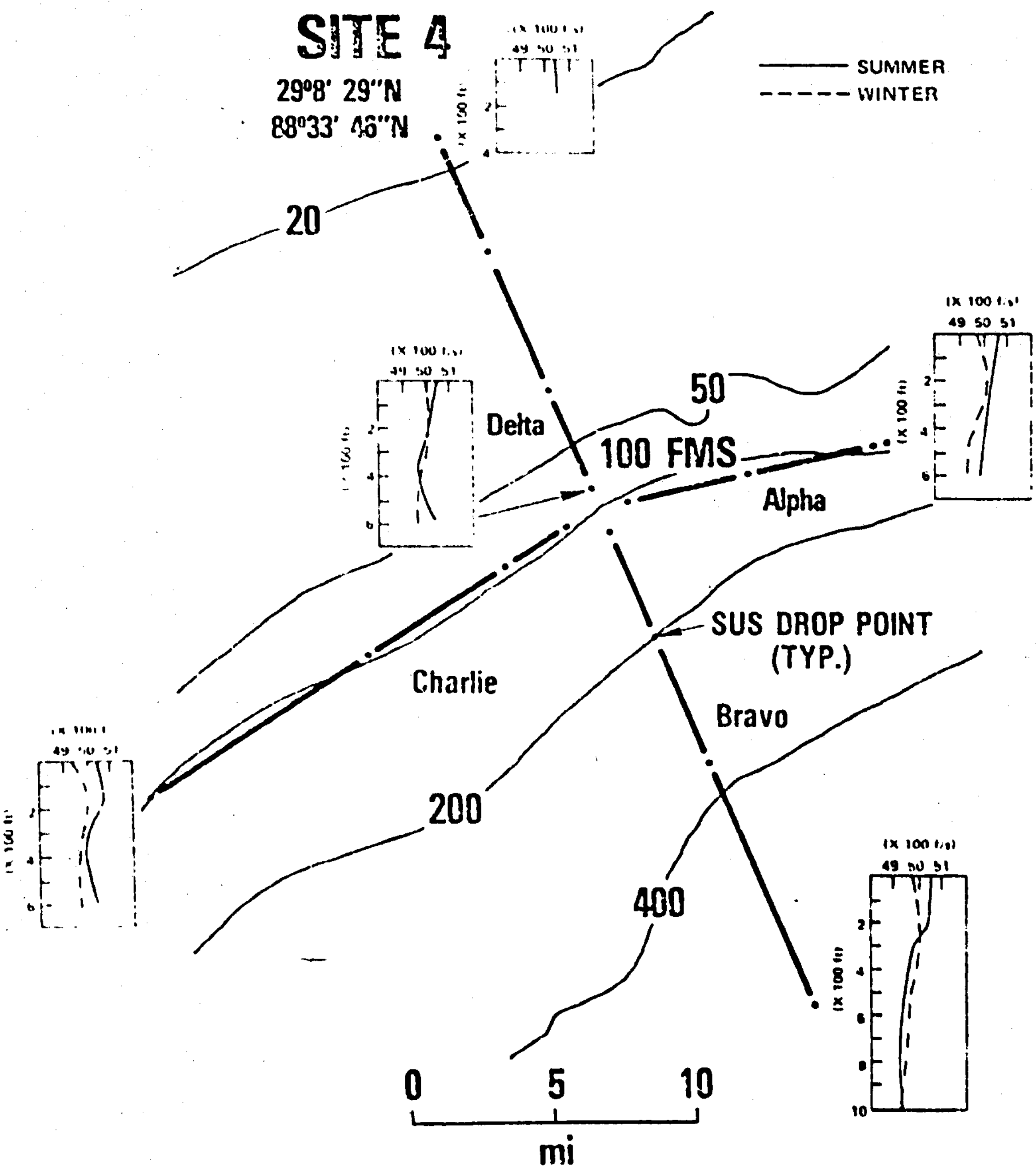
at regular intervals to a range of 600 miles. The received signals were recorded on magnetic tape and later analyzed through 1/3 octave filter bands for the frequency range 50-630 Hz. This data is presented in the form of transmission loss vs range.

(U) The data from WOL and NOL experiments was taken at four shallow water sites off the west coast of Florida and off New Orleans. Each of these experiments consists of a pattern of SUS dropped within a 20 to 30 nm radius of a receiver (see Figure 3-2). Each of these was on the shelf in shallow water. The NOL data is presented in the form of transmission loss contours (see Figure 3-3). The WOL data is presented in the form of transmission loss vs range (see Figure 3-4). The NOL data is presented for adjacent octave bands centered at 63, 125, 250, 500, 1000, 2000 and 4000 Hz. The WOL data is for the same frequencies with the omission of 4000 Hz.

(U) The NAVOCEANO data is for 64 stations in the Gulf of Mexico. Each station had a SUS run of approximately 15-20 nm extent. Unfortunately, the lowest frequency ~~for~~ which the signals were analyzed was 500 Hz.

(U) In addition, NADC data was obtained for two sites, one in the Yucatan Basin and another off the shelf west-southwest of Key West.[5] Both sites are in deep water with a 300 ft source (SUS) and 800 ft receiver. A single SUS run of about 50 nm length was accomplished at each site. This data was presented in tables of transmission loss in octave bands from 63 Hz as a function of range.

(U) The CHURCH GABBRO exercise represents the best source of propagation loss data available in the Cayman Trough. Propagation loss measurements were conducted in the Cayman Trough as part of the CHURCH GABBRO exercise. CW acoustic sources were unreliable and intermittent so only SUS results were discussed in the analysis reports.



(1 FATHOM - 1.83 meters 1 FT. - .304 meters 1 MILE - 1.85 km.)

Figure 3-2 (C) BATHYMETRY, SOUND SPEED PROFILES AND SUS DROP POINTS FOR SUMMER AND WINTER CONDITIONS AT SITE 4 (NEW ORLEANS) (U)

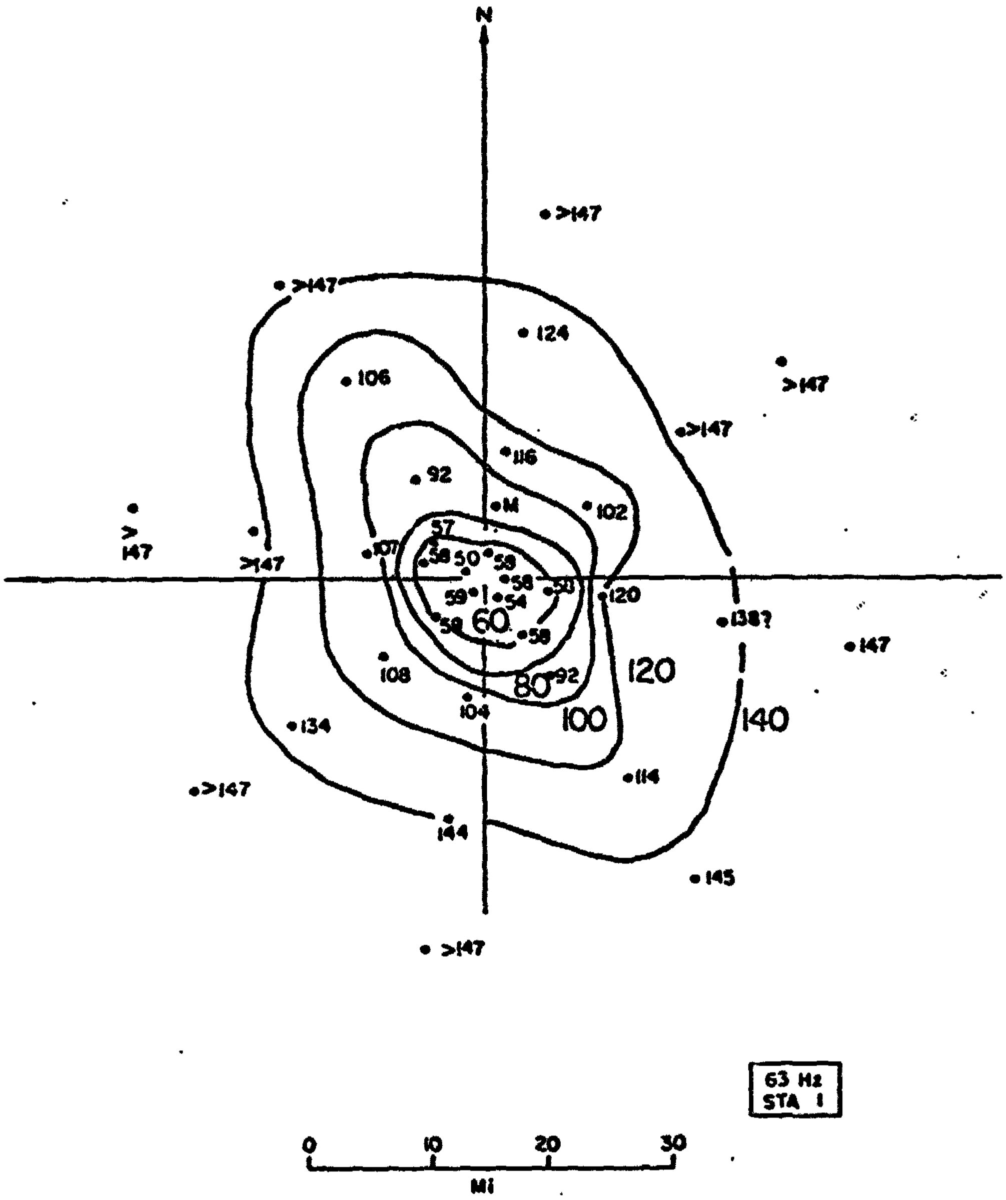


Figure 3-3 (C) NOL Transmission Loss Contour Plots (U)

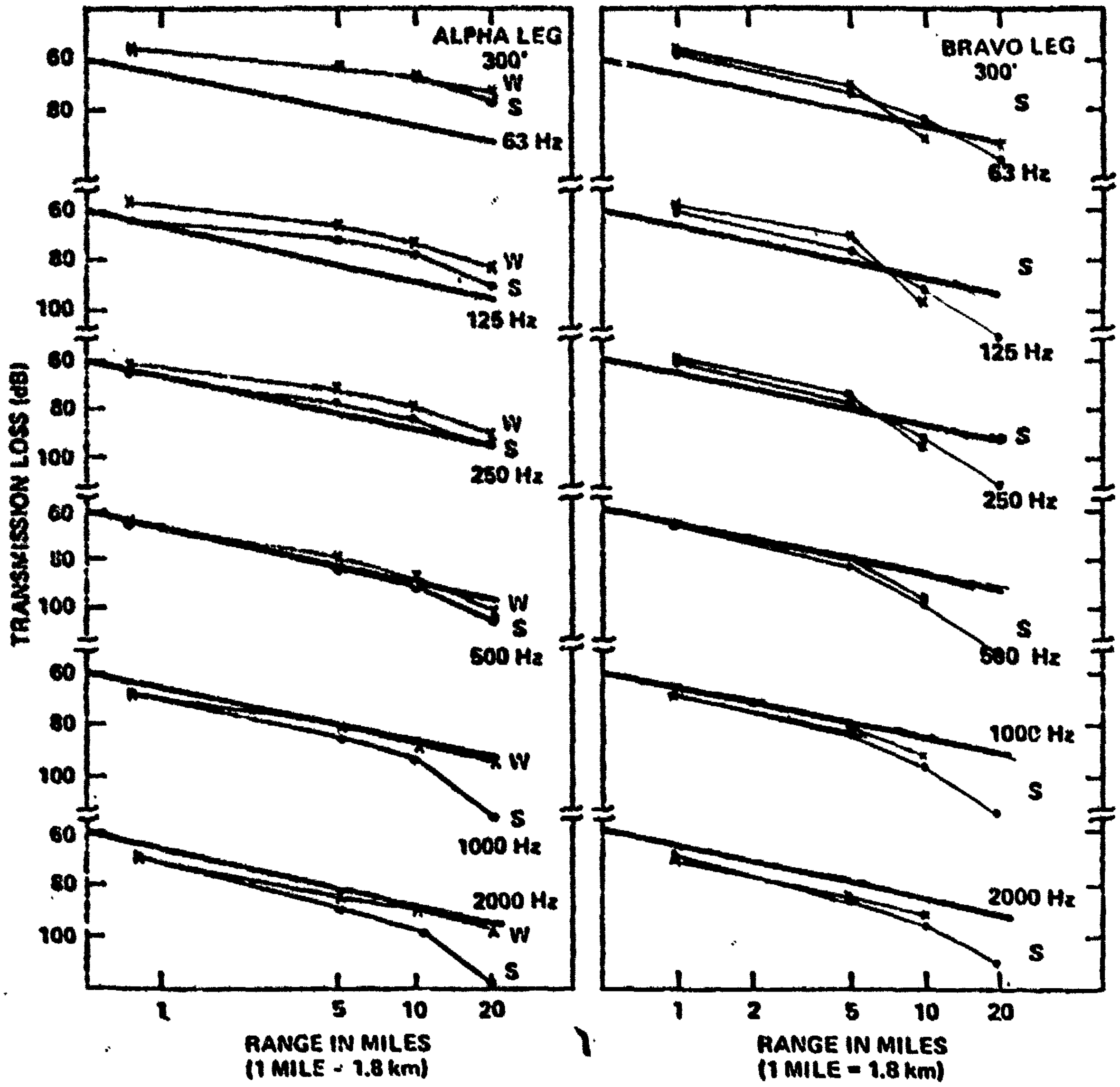


Figure 3-4 (C) SUMMER AND WINTER TRANSMISSION LOSS VERSUS RANGE WITH A 300 FT. SOURCE DEPTH FOR ALPHA AND BRAVO LEGS AT SITE 4 (U) (RECEIVER AT 300 FT)

(U) Ship-dropped SUS were received at two locations by ACODACs, one near the middle of the Trough, 140 nm WNW from Montego Bay, Jamaica, the other at the far southwest end of the Trough (see Figure 3-1). Each ACODAC sampled the SOFAR channels from near the axis to the critical depth with six hydrophones (see Table 3-1 and Figure 3-5).

(U) Aircraft SUS runs were received by TABS and calibrated AN/SQQ-57 sonobuoys (see Figure 3-6) located about midway between the ACODACs.

(C) Transmission loss results are dominated by the effects of the topography. In the short ranges from the southwest measurement point (out to 160 nm) a complete SOFAR channel exists, but the convergence zone structure which would be expected in the open ocean is smoothed by the large amount of reflected energy from the lateral topography. At long ranges (beyond 450 nm) the intermediate ridge structure baffles the acoustic energy, but as range increases out to 600 nm this effect is offset by others such as bathymetric focusing, which results in an anomalous curve, i.e., the reduction of transmission loss with increasing range. One of the objectives of the exercise was to search for depth dependence in transmission loss. A very sharp depth dependence was found, sometimes as high as 10 dB between adjacent hydrophones, but this effect was intermittent and was a strong function of range, occurring in a regular pattern relative to the positions of the convergence zones. In general, the largest signals were received in the vicinity of the critical depth.

(U) Transmission loss plots for 50 Hz, 1/3 octave band for ACODACs and 25, 50, 100, 160, 200, 400 and 800 Hz, 1/3 octave bands for TABS and sonobuoys are presented in the analysis reports.

(U) The KIWI exercise, WOL and NOL experiments represent the best sources of transmission loss data for the Gulf of Mexico. The KIWI data was collected along the run shown in Figure 3-1. The WOL and NOL experiments were conducted at the sites shown.

Unit No.	Position H 3	Position D 2	Position B 4
Position	Lat. 20-00.2N Long. 85-58.7W	Lat. 17-34.3N Long. 86-00.5W	Lat. 18-49.0N Long. 79-52.7W
Hyd. #1	595m	508m	* 966m
Hyd. #2	1205m	1119m	1576m
Hyd. #3	2426m	2341m	2757m
Hyd. #4	4137m	4053m	4410m
Hyd. #5	4443m	4358m	4715m
Hyd. #6	4535m	4450m	4806m
Bottom	4593m	4500m	*4846m
Recording Intervals			
Start	29 Nov 1504Z	28 Nov 2232Z	30 Nov 2310Z
Stop	**6 Dec Z	9 Dec 0349Z	11 Dec 1510Z

(U) TABLE 3-1 (U) SENSOR DEPTHS FOR ACODACS IN THE CAYMAN TROUGH (U)

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* Depths confirmed by recording pressure gauges.

** Estimated time of breaking loose derived from character of recorded signals.

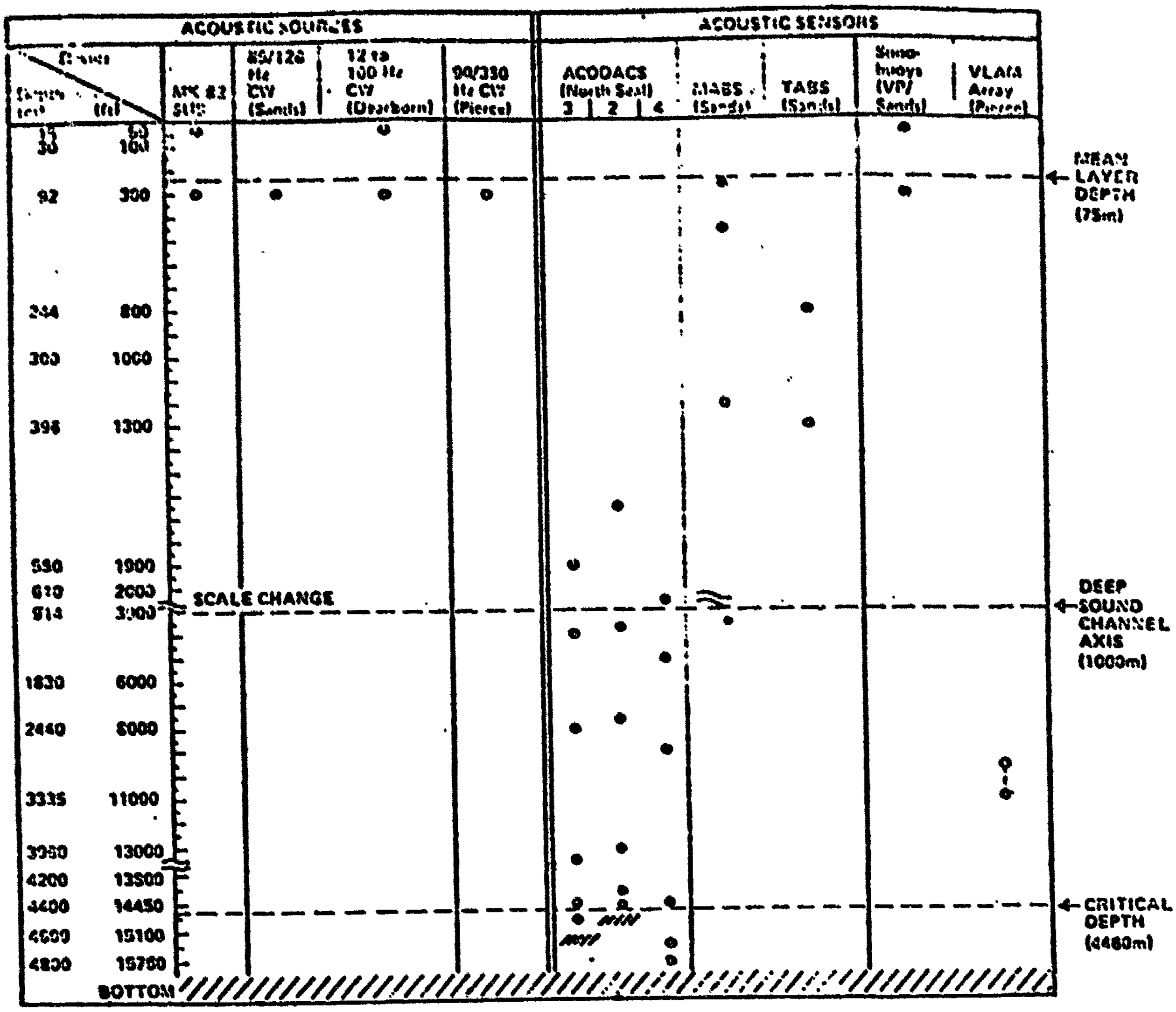


FIGURE 3-5 (U) Source and Sensor Depths CHURCH GABBRO Exercise (U)

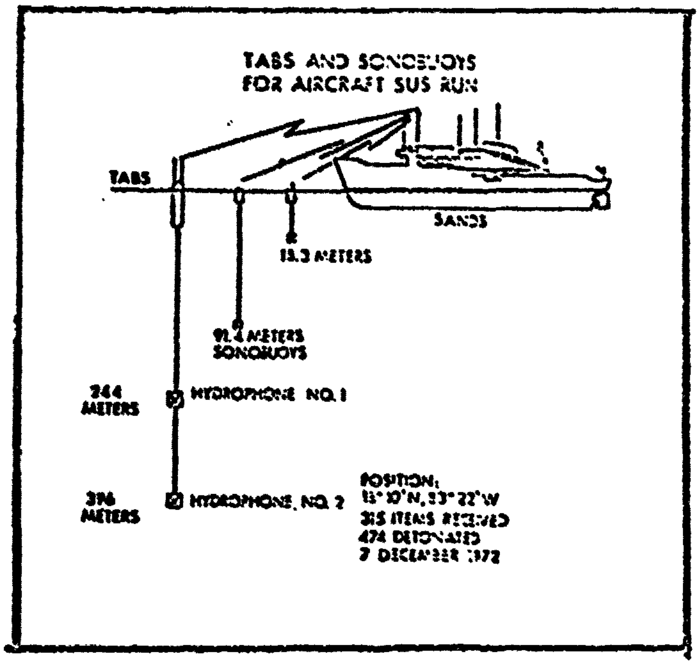


Figure 3-6 (U) TABBS AND SONOBUOY LOCATIONS FOR AIRCRAFT SUS RUNS, CHURCH GABBRO EXERCISE (U)

(U) During the KIWI exercise the received acoustic signals during the propagation runs were recorded on magnetic tape from the outputs of hydrophones at 800 and 1500 ft. These hydrophones were on a single wire array that was hard-wired to the USNS SANDS. Constant high seas and winds (20-25 knots) caused the SANDS to sail and pull the array along, causing severe strumming noise below 100 Hz. Another hydrophone system was also employed, a single hydrophone at 1500 ft suspended below a telemetering buoy not hard-wired to the ship. The telemetering buoy system was much quieter than the hard-wired array. One point of interest is that the SANDS was subjected to surface currents of 2 kt at the Gulf of Mexico station.

(U) The propagation loss data was processed in selected 1/3 octave bands from 25 Hz to 1000 Hz. This data indicates, as would be expected, that propagation between points in the deep channel is good.

(U) An indication of the amount of noise which propagates off the shelf can be derived from the NSWC/WOL and NOL experiment data. This data was collected along the West Florida Shelf and off New Orleans. Figure 3-3 shows a transmission contour plot of data taken during the NOL exercise off the West Florida Shelf. When viewed in conjunction with the bottom contours (see Figure 3-7), it can be seen that propagation in water of constant depth is better than either upslope or downslope propagation. The NOL data shows relatively high loss, as much as 140 dB, to ranges of less than 30 nm. Figure 3-2 shows the experimental layout for the NSWC/WOL experiment off New Orleans. Transmission loss for the Bravo and Alpha legs at 63 Hz is shown in Figure 3-4. Note that the propagation loss is significantly lower than that observed on the West Florida Shelf, indicating the high variability that can be expected in different shallow water regions along the Gulf Coast. Comparing the transmission loss for the downslope and cross-slope conditions, it can be seen that the downslope propagation loss (assuming source-receiver reciprocity) at 15 nm is 25-30 dB (see Figure 3-4) greater than along a path with constant water

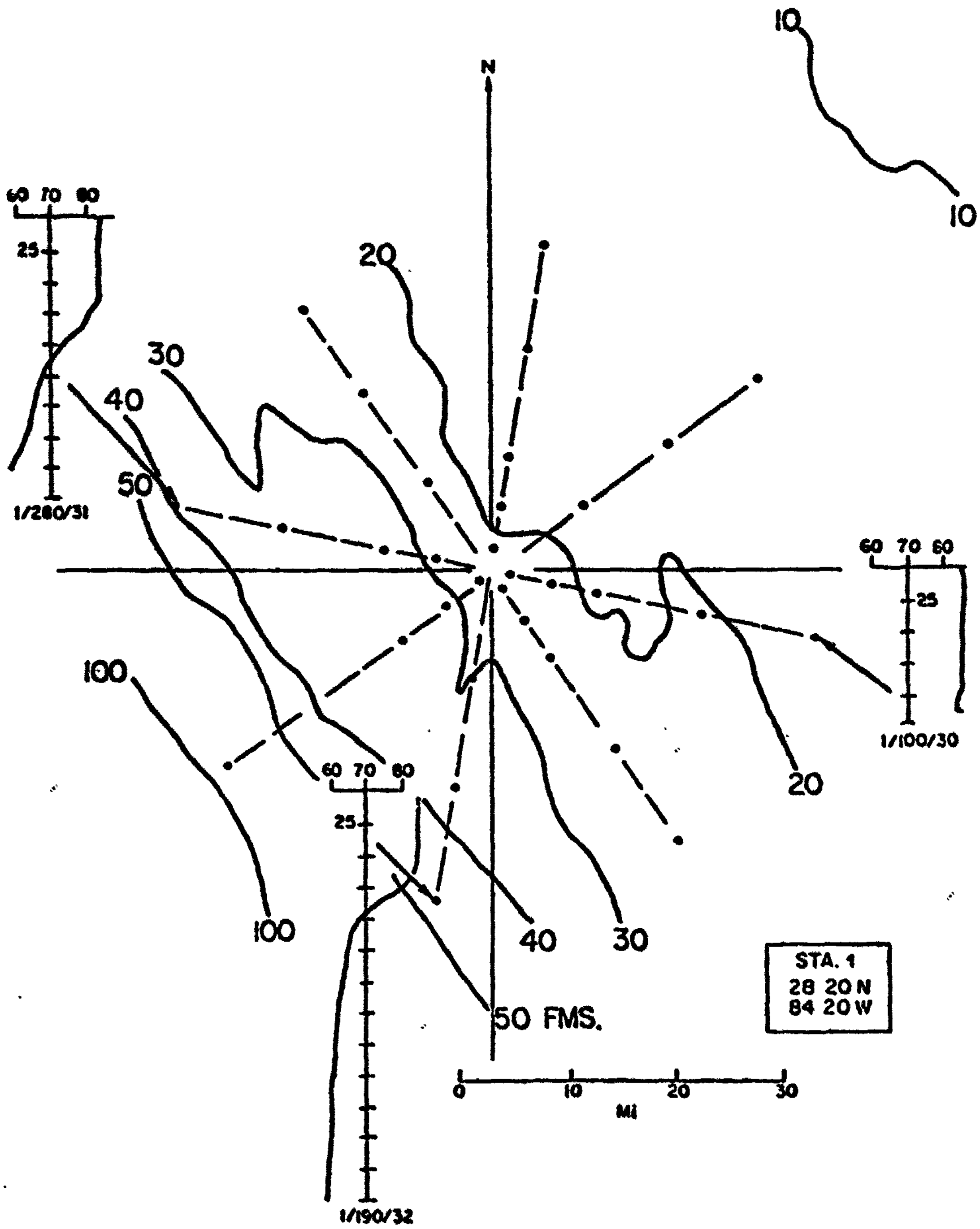


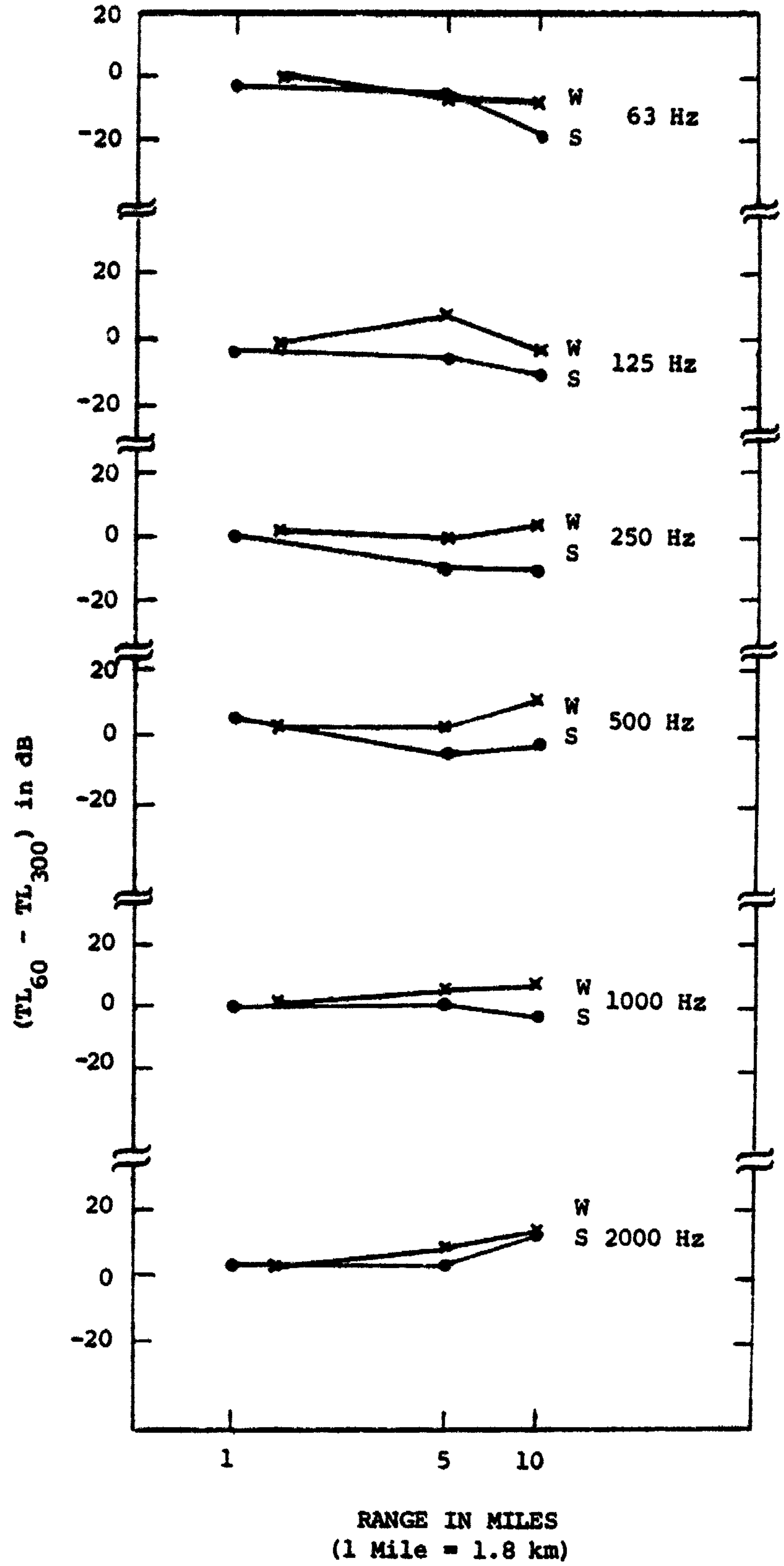
FIGURE 3-7 (C) NOL Bathymetry Contours (U)

(U)

depth. Figure 3-8 shows a comparison of downslope propagation loss for the 60 and 300 ft depth sources. Note that for the 300 ft depth sources, the propagation loss is significantly lower at the maximum measurement range of 20 nm.

(U) These experimental results agree in general with the model runs performed by NORDA 320 and discussed in Chapter 4 (see Figure 4-13). In essence, these predictions indicate that downslope conversion occurs with good propagation from shallow sources into the deep sound channel. The substantial decrease in propagation loss for the 300 ft sources as contrasted with the 60 ft sources along the Bravo leg are in agreement with this prediction.

(U) Combining the indications from the KIWI, WOL, and NOL data there is a strong indication that noise generated on the shelf by oil industry-related sources may propagate off the shelf and into the sound channel, and then to substantial ranges with fairly low loss. For receivers substantially below or above the sound channel, the noise should be attenuated far more rapidily.



(C) FIGURE 3-8 Difference between Transmission Loss versus Range for source depths of 60 and 300 feet (TL_{60} - TL_{300}) on BRAVO leg for summer and winter at the indicated frequencies. (U)

3.1.2 (U) Representative Propagation Loss Data (U)

(U) Propagation loss data from the various sources is presented in two primary forms. The NOL data is in the form of transmission loss contour plots as in Figure 3-3. All the data from the other sources is presented in the form of plots of transmission loss vs range. Figure 3-4 shows a sample of this type. Full data presentations for each of the sources can be found in the references for these sources.

3.1.3 (U) Coherence and Array Signal Gain (U)

(U) Spatial coherence is the degree to which the signal received by one hydrophone is similar to that at another some distance away. In separate experiments, the spatial coherence of signals was investigated by using a number of hydrophones placed in a horizontal or vertical string. The tape-recorded signal for different pairs of hydrophones was correlated by means of a Deltic Correlator, and the correlation coefficient was obtained as a function of separation and frequency. For the horizontal case in 200 ft of water,[11] the coefficient decreased with spacing in a way consistent with theory based on horizontally-isotropic signals. But for a vertical string, also in 200 ft of water,[12] the correlation coefficient fell off much less rapidly with increasing spacing, so as to indicate that the signal was coming from a narrow vertical angle above and below the horizontal. This angle, which can be called the coherence angle, varied with frequency and time in the manner shown in Figure 3-9. The coherence angle was found to decrease with increasing time and increasing frequency. This suggests that signals arriving from high angles relative to the horizontal are stripped off, so to speak, by the increased attenuation produced by the greater number of encounters with surface and bottom at the greater angles. The size of the coherence angle is important for array design. This is illustrated in Figure 3-10, which shows the computed array gain of a vertical array having a variable number of elements spaced one foot apart, against isotropic noise and against shallow water reverberation. This shows that an array of a particular

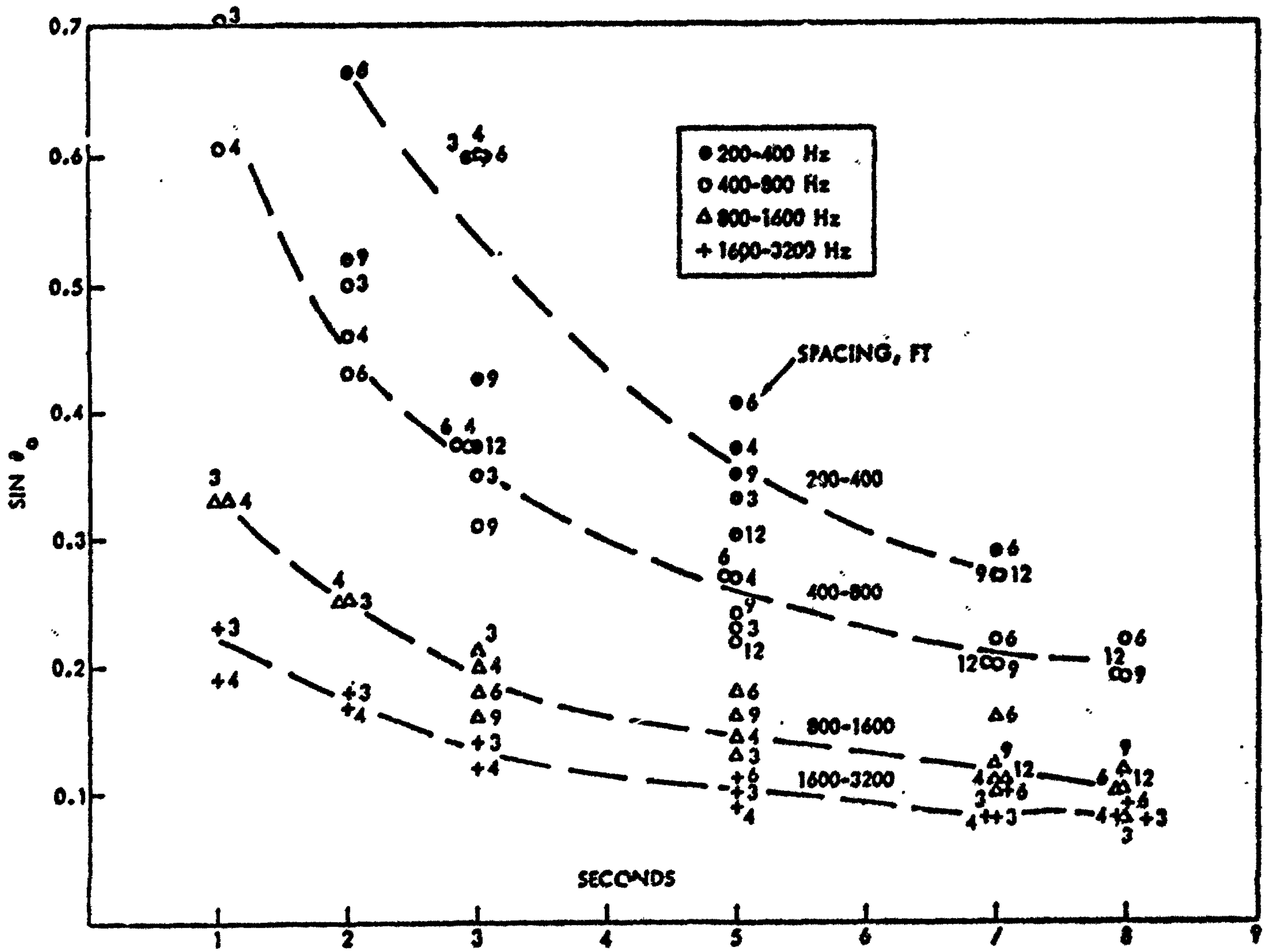


FIGURE 3-9 (U) Coherence angle θ_o of reverberation at different times in different octave bands. θ_o is the angle from the horizontal within which the reverberation may be expected to be arriving. The numbers alongside each point give the hydrophone separation for each determination. (U)

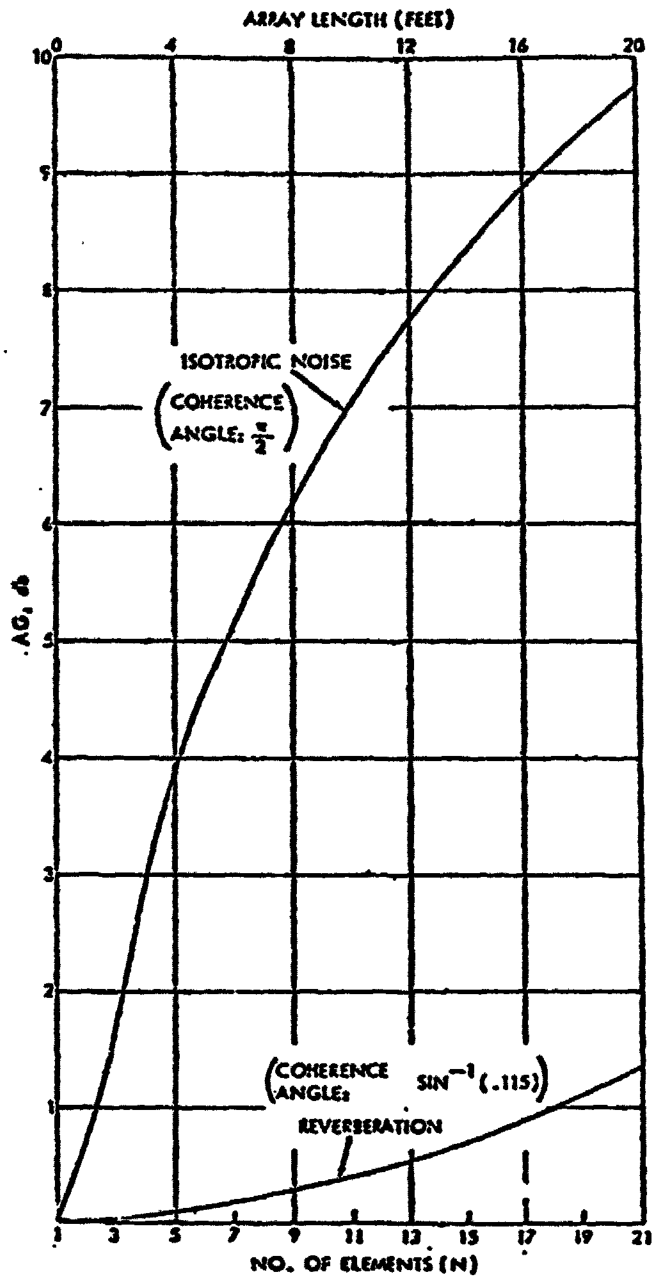


FIGURE 3-10 (U) Comparisons of the array gain (AG) of a vertical array against isotropic noise and shallow-water reverberation. The array has a variable number of elements placed one foot apart. The sine of the coherence angle is taken as .115 (θ_0=6.6°) at a frequency of 1120 Hz. (U)

(U)

length would have poorer rejection (smaller array gain) of signal than of noise because of the small size of the coherence angle.

3.1.4 (U) Adequacy of Propagation Loss Data to Describe the Environment (U)

(U) The CHURCH GABBRO data describes the Cayman Trough acoustically in good detail.

(U) KIWI, WOL, and NOL data provide limited information on the Gulf of Mexico. This area has many interesting features for which the upcoming exercise should provide some insight, such as propagation off the shelf area and into deep water and propagation along paths at various angles relative to the bottom contours.

3.1.5 (C) Description of the Propagation Environment (U)

(C) The transmission loss results in the Cayman Trough showed the effects of the peculiar geometry of that region. Strong evidence of bathymetric focusing, i.e., the coupling of acoustic energy into the sound channel from bottom reflections, is found in the longer range (i.e., greater than 450 nm) portions of the runs. At these ranges where the source was near position A (see Figure 3-1), one sees an increase in signal (decrease in transmission loss) with increasing range.

(U) Another boundary effect in both reflection and scattering was the obliterating of the strong convergence zone structure seen in SOFAR propagation in the open ocean. That the convergence zones were functioning is shown in the sharply range-dependent depth effect seen in the relative transmission loss.

(U) Available sources indicate that propagation in shallow water on the shelf area off of West Florida is better along paths with constant depth than along either upslope or downslope paths. There is also evidence that propagation loss on the shelf is low enough to encourage downslope conversion of acoustic energy into the sound channel. Once in the sound channel in deep water, the sound should propagate with very low loss.

3.2 (C) Ambient Noise (U)

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(C) Very few ambient noise measurements have been made in the Gulf of Mexico, the largest basin of the CHURCH STROKE II exercise area. Because the Gulf is bottom-limited, it is anticipated that shipping effects will be local, thus causing large variations in noise levels as a function of time and place. Petroleum industry activities are concentrated on the continental shelves, and noise from these is anticipated to propagate throughout the Gulf near the channel axis due to downslope conversion. The effects of the petroleum industry will be discussed in Section 3.3.

(U) The entrances to the Gulf, the Yucatan Basin, and the Cayman Trough are limited in a real extent and limited in acoustic communication with other areas due to bathymetry, so that the noise levels below 200 Hz are highly variable as a function of time and place.

3.2.1 (C) Sources and Locations of Data (U)

(C) The Environmental-Acoustics Atlas of the Caribbean Sea and Gulf of Mexico, Volume 1 lists and selectively presents a summary of the sources and locations of ambient noise data published prior to 1972 (Reference 30). The summary shows that the small amount of existing data for the exercise area was mostly acquired and processed by the University of Miami in the 1953-1954 time frame; there is one lone data point south of New Orleans from an ASW panel summary report.

(U) A literature search has uncovered additional sources and locations of data, including numerous sonobuoy measurements made by NADC and NAVOCEANO in the Cayman Trough, Yucatan Basin and Yucatan Channel areas. Figure 3-11 shows the locations of the data; the numbers in the figure correspond to the applicable references. Table 3-2 summarizes the available omnidirectional noise data in terms of such general parameters

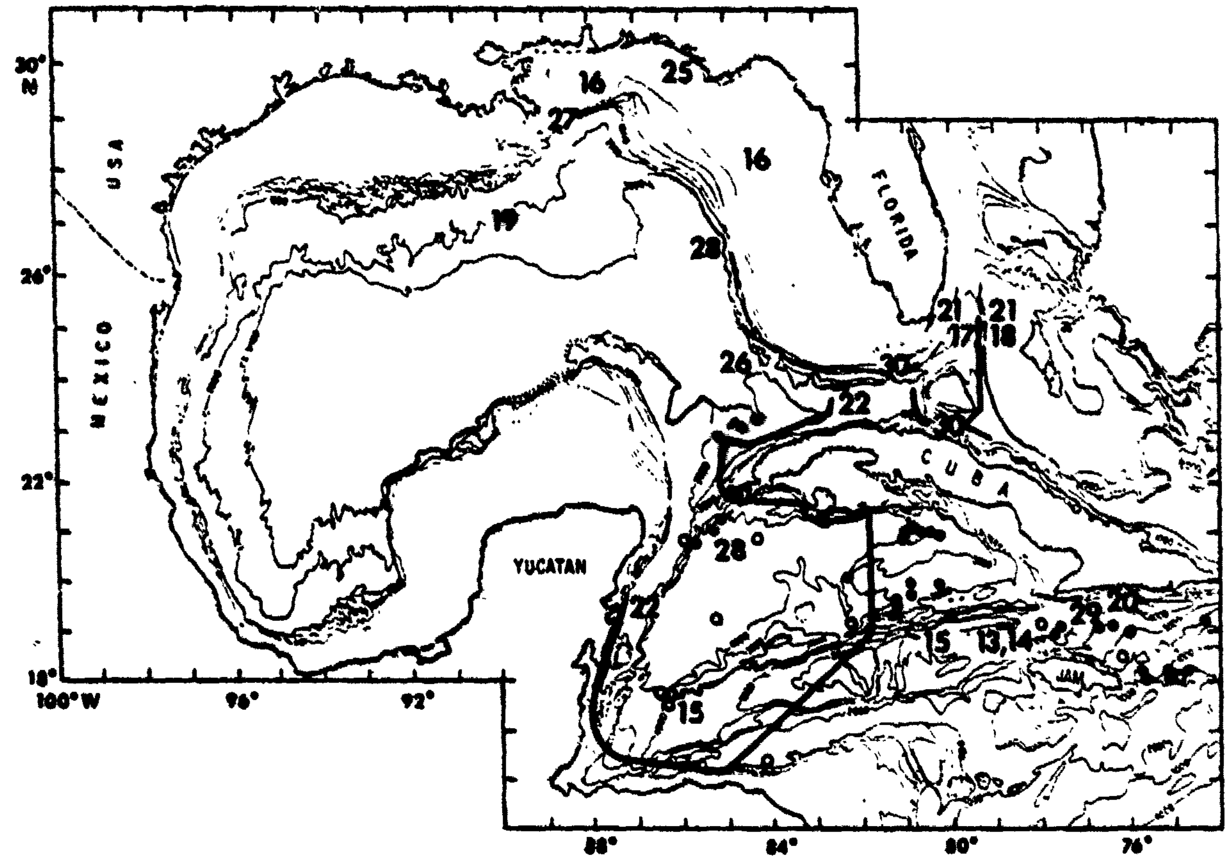


Figure 3-11. (C) Locations of Ambient Noise Data (U).
Numbers are reference numbers.

TABLE 3-2 . (C)OMNIDIRECTIONAL AMBIENT NOISE LOCATION MEASUREMENTS(U)

Ref. No.	Time of Measurement	General Location	Coordinates	Measurement Depth (m)	Frequency (Hz)	Resolution	Length of Data Base	Remarks
13	3-6 Dec 72	Cayman Trough	19°00N 79°00W	2,865	0-520	1.375 Hz	4 days[2]	7 spectra for 2 channels averaged over 3 min
15	Nov-Dec 72	Cayman Trough	18°49N 79°53W	966 1,576 2,757 4,410 4,715 4,806	16-315	1/3 octave	≈10 days	Data processed for entire period, 1 min averages. Inertial and tidal power determined, autocorrelation computed
			17°34N 86°00W	508 1,119 2,341 4,043 4,358 4,450	16-315	1/3 octave	≈10 days	
16			17°47N 86°21W	19-91	25,50,100,200	1/3 octave	1 hr	8 sec samples were averaged for length of data base
			17°57N 86°22W	19	25,50,100,200		1 hr	
			17°38N 86°19W	91	25,50,100,200		1 hr	
			19°10N 78°00W	91	25,50,100,200		15 min	
			19°10N 82°25W	91	25,50,100,200		15 min	
			20°50N 84°15W	91	25,50,100,200		15 min	
			20°45N 85°50W	91	25,50,100,200		15 min	
			19°15N 85°15W	91	25,50,100,200		15 min	
			16°20N 84°05W	91	25,50,100,200		15 min	
			18°35N 76°25W	91	25,50,100,200		15 min	
			18°05N 74°55W	91	25,50,100,200		15 min	
	Last week of August 1969	NE Gulf	29°30N 80°00W	27	60-2000	1 octave	1.5 hr[2]	4 short samples averaged, used SSQ-48 sonobuoys

See page 3-23 for Footnotes

TABLE 3-2. (C) OMNIDIRECTIONAL AMBIENT NOISE LOCATION MEASUREMENTS (Cont'd) (U)

Ref. No.	Time of Measurement	General Location	Coordinates	Measurement Depth (m)	Frequency (Hz)	Resolution	Length of Date Base	Remarks
17	March 66	Bimini		33	25,100,400, 1000		18 days	Processed for entire time span including periodograms
18	18 Feb - 2 May 67	Bimini		33	25,100,400, 1000	12,65,100, 600 Hz	74 days	
19		South of Miss. Delta	27°N 90°W		100,3500		?	Origin of data not described
20	August 70	Off Guantanamo	19°30N 76°30W	Surface	3500	500 Hz	several[2] days	Data condensed from paper chart recording of test set.
21	1970	Fowey Rocks Bimini	25°35N 80°W 25°45N 79°20W	305 30 & 366	420	0.013 Hz	19 days[3]	Extensive study on S/N, phase etc.
22	1954	W. Caribbean & Yucatan Channel		61	40-12,000		15 sec[1]	Processing BW not specified, possibly 1/3 or 1/2 octave
23	17-26 August 71	Yucatan Basin Cayman Trough Yucatan Channel		29	100,200 440,1000	50 Hz	1 min[1]	Ambient noise meter reading (SSQ-57)
24	Mar-Apr 1971	Venezuelan Basin	16°45N 70°45W 14°20N 70°36W	4120 3777	25,50,100,200	1/3 octave	6 days	Levels are reduced to 7 Hz bandwidth, all data was processed
25	1976	Panama City		30	3-500		several[2] says	Average levels over 2 propagation runs
26	August 72	West of Key West	24°30N 85°00W	27	100,200, 440,1000	50 Hz	1 min[1]	Ambient noise meter reading

See page 3-23 for Footnotes

TABLE 3-2. (C) OMNIDIRECTIONAL AMBIENT NOISE LOCATION MEASUREMENTS (Cont'd) (U)

Ref. No.	Time of Measurement	General Location	Coordinates	Measurement Depth (m)	Frequency (Hz)	Resolution	Length of Data Base	Remarks
27	Sept 75 to Jan 76	South of New Orleans	29°08N 88°34W	91 18	50-2000	1/3 octave	4 hr[2]	Several samples with 32 sec averaging times, SSQ-57A
28	18 May 72	Yucatan Basin	≈20°40N 85°00W	762 1220 1372	16-2500	1/3 octave	30 min	Mean value of successive 5 sec averages
	20 May 72 23 May 72	Gulf of Mexico	≈26°40N 85°25W	244 457 762 1006 1463	16-2500	1/3 octave	30 min	
29	Nov-Dec 72	Cayman Trough	19°10N 76°45W	128	50,100,200	1/s octave		Only data from one sensor above 25 Hz considered possibly uncontaminated (Reference 2)

[1]Averaging, integration or processing sample length. If more than 1 processing interval is used it is not known.

[2]The ambient noise data was collected during a signal propagation experiment; ambient noise values are obtained between signals several times during data base period.

[3]Ambient noise levels were obtained for bands adjacent to the source frequency.

(U)

as measurement depth, water depth, acquisition time frame and bandwidth. Some data sources outside the exercise area are included to infer background noise levels at nearby locations within the area of interest.

(C) The more recent available data are derived from three general sources: the CHURCH GABBRO exercise in the Yucatan Basin and the Cayman Trough in 1972; the KIWI experiment in the Yucatan Basin and the eastern Gulf of Mexico, also in 1972; and sonobuoy data acquired by NADC during 1971, by NAVOCEANO during CHURCH GABBRO in 1972, by the U.S. Navy during a FIXWEX Training mission in 1972, and by NOL (now NSWC) during their Shallow Water program in 1975 and 1976.

(C) Ambient noise data from the CHURCH GABBRO exercise are discussed in detail in Reference 15. Ten days of data from two ACODACs with sensors distributed throughout the water column (location 15 in Figure 3-11) were processed and extensive statistical descriptors were developed. A Vertical Line Array Measurements (VLAM) array was installed at location 13, 14 in Figure 3-11 at a depth of approximtely 4200 m. The resulting data have been extensively analyzed for vertical noise directionality by both NADC and NUC (now NOSC) (References 13 and 14). Data were obtained at location 29 in Figure 3-11 by the Moored Acoustic Buoy System (MABS) and were processed by NUSC/NL (Reference 29).

(C) Ambient noise measurements during the KIWI experiment in May 1972 were obtained using Autobuoy. A dive was made in the northern part of the Yucatan Basin (location 28 in Figure 3-11) and 30 min noise recordings were made at 762, 1220 and 1372 m depths. Two dives were performed near the steep continental slope west of Tampa, and on each dive recordings were obtained at five programmed depths.

(C) Ambient noise measurements made with sonobuoys were performed at several locations in the eastern Gulf of Mexico and in numerous locations throughout the Caribbean Sea and its approaches. A majority of these

(C)

measurements were made by NADC in August 1971 using SSQ-57 sonobuoys and readings were taken in the aircraft at 100, 200, 440 and 1000 Hz on a Sea Noise Meter. The locations of these readings are shown in Figure 3-11 as "●". During CHURCH GABBRO, NAVOCEANO gathered data at eleven locations ("o" in Figure 3-11); the data were processed using 1/3 octave filters. Location 26 in Figure 3-11 is the site of the FIXWEX-ALPHA-73 data which were also obtained from Sea Noise Meter readings. NSWC has made noise measurements at three shallow-water locations from New Orleans to Tampa (locations 16 and 27 in Figure 3-11) with sonobuoys utilizing either 1/3 or 1 octave processing.

(C) The vertical directionality of noise was determined using VLAM during the CHURCH GABBRO exercise. The center of the array was positioned at about 2800 m at location 13, 14 in Figure 3-11. Table 3-3 shows various parameters associated with the measurements. The data were processed and analyzed both by NUC (now NOSC) and NADC (References 13 and 14).

(U) No reports of horizontal noise directionality measurements were found during the literature search.

3.2.2 (C) Omnidirectional Noise Measurements (U)

(U) Ambient noise measurements were made in the CHURCH STROKE III area, first by the University of Miami in 1953 and most recently by NSWC in 1976 (References 22 and 27). Figure 3-12 shows the locations of measurements made since 1970 in the areas of interest. Table 3-4 shows typical values of ambient noise for each of these measurements. The measurements are presented, by geographical area, in the following sections.

3.2.2.1 (C) Gulf of Mexico (U). Measurements in the Gulf of Mexico are limited to the eastern Gulf. The petroleum industry is expected to contribute significantly to the background noise level, although there are no known measurements to support this conjecture.

TABLE 3-3 . VERTICAL AMBIENT NOISE DIRECTIONALITY MEASUREMENTS

Ref. No.	Time of Measurement	General Location	Coordinates	Measurement Depth (m)	Frequency (Hz)	Aperture (m)	Resolution (Hz)	Length of Data Base	Remarks
13	3-6 Dec 72	Cayman Trough	19°00N 79°00W	2800	21.37 to 421.37	109.73	1.375	4 days	PRAZ Displays
14	3-6 Dec 72	Cayman Trough	19°00N 79°00W	2800	12-512	109.73 23 beams	0.086 to 1.375	4 days	In depth analysis of vertical directionality

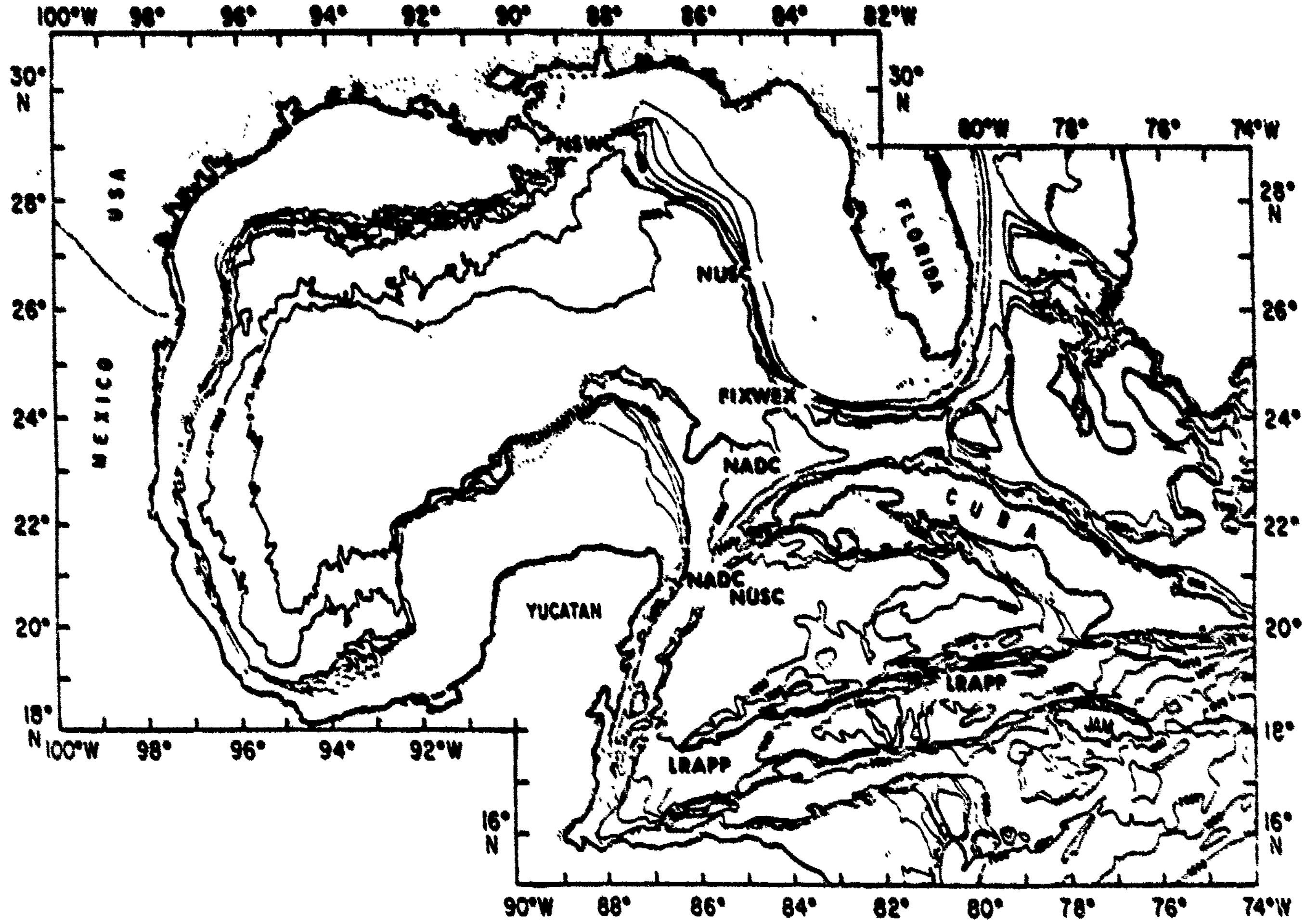


Figure 3-12 (C) Locations of Data Acquired After 1970 in Areas of Interest (U)

By acquisition agency.

TABLE 3-4. (C)TYPICAL AMBIENT NOISE LEVELS(U)

	WATER DEPTH (FT)	HYDROPHONE DEPTH (FT)	LEVEL dB//1μPa 50 Hz	100 Hz
GULF OF MEXICO				
NSWC Summer 75		60	74	68
	600	300	82	76
Winter 76		60	80	77
		300	84	80
NUSC Spring 72	10400	1770	85	78
FIXWEX Summer 72	10800	90	-	70
NADC Summer 71	≈8000	95	-	77
N. W. CARIBBEAN				
NADC Summer 71	≈10500	95	-	78
NUSC Spring 72	≈12000	4000	85	76
LRAPP Winter 72				
Site B	4833	966	83	78
Site D	4509	1119	76	70

(C) South of New Orleans. NSWC made omnidirectional noise measurements using SSQ-57A sonobuoys at the continental shelf-slope intersection off the Mississippi delta (Reference 27). The location (location 27 in Figure 3-11) is near both petroleum offshore activity and shipping lanes. Figure 3-13 shows the range of noise levels observed and the average levels for measurements made during September 1975 and January 1976. The relatively high noise levels are attributed to the closeness of the site to industrial activity.

(C) West Florida. Measurements were made during Project KIWI off the West Florida Escarpment west of Tampa on May 20 and 23, 1972 by NUSC/NL (location 28 west of Florida in Figure 3-11). The data have been presented at a professional meeting but have not been published (Reference 28). Figure 3-14 shows ambient noise spectra observed for five depths. The results are sensibly uniform; no significant depth dependence is evident. The levels are similar to those observed south of New Orleans, which reflect the high level of industrial noise. During the measurements, seismic profiler signals were identified. Noise processing was performed between the pulses.

(C) Urick made measurements on the West Florida Shelf in August 1969 to the northeast of the KIWI measurements (Reference 16). Location 16 on Figure 3-11 indicates this site northeast of location 28, plus one south of Mobile. Figure 3-15 shows the noise levels measured at both sites using SSQ-48 sonobuoys. Location 16 west of Tampa on the West Florida Shelf is much quieter than either location 28 of the KIWI experiment or Location 27 south of New Orleans. Location 16 south of Mobile is much noisier than the others. Thus one can conjecture that the West Florida Shelf was quiet and free of industrial noise sources at the time of the measurements.

(C) Southern Straits of Florida. Figure 3-16 shows noise data based on measurements made in the southern Straits of Florida by the University of Miami in 1954, and at the western entrance to the straits by the U.S.

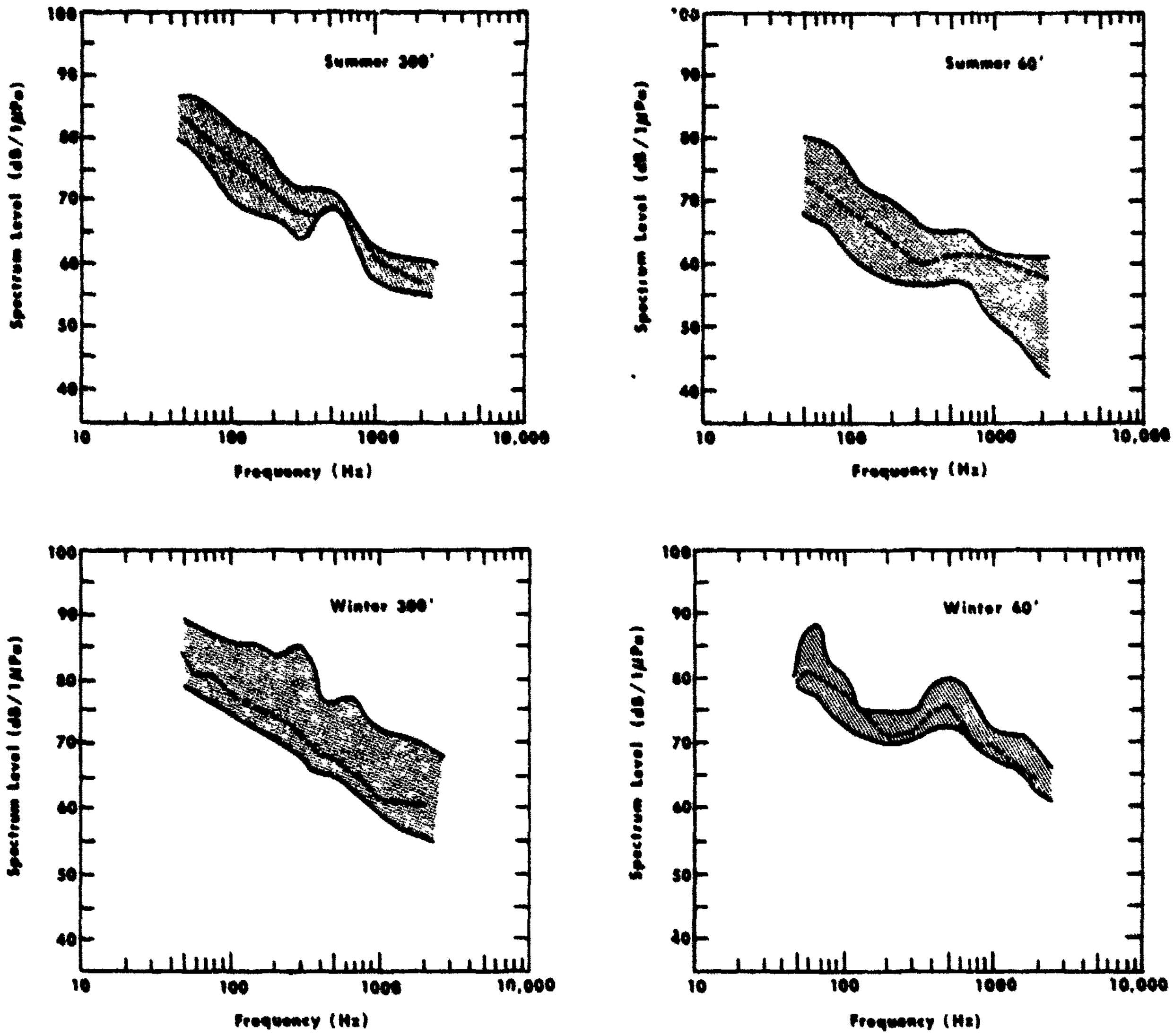


Figure 3-13. (C)Minimum and Maximum Levels of Ambient Noise for Shallow (60 Ft) and Deep (300 Ft) Hydrophones at Site South of New Orleans(U)

Dotted lines show average. From Reference 27.

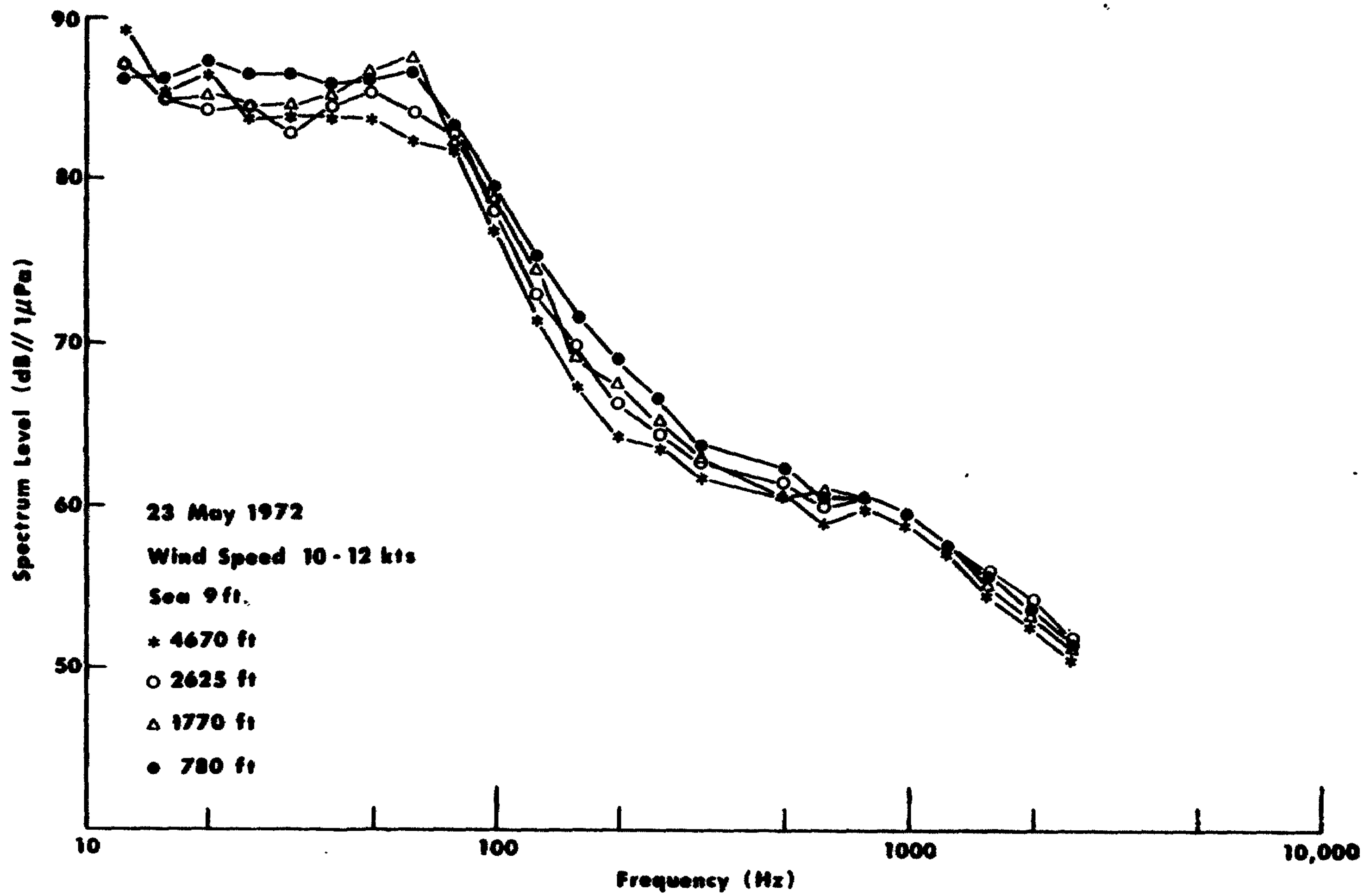


Figure 3-14. (U) Ambient Noise Spectra from KIWI Station 9, Gulf of Mexico, Dive 2. (U)

Reference 28.

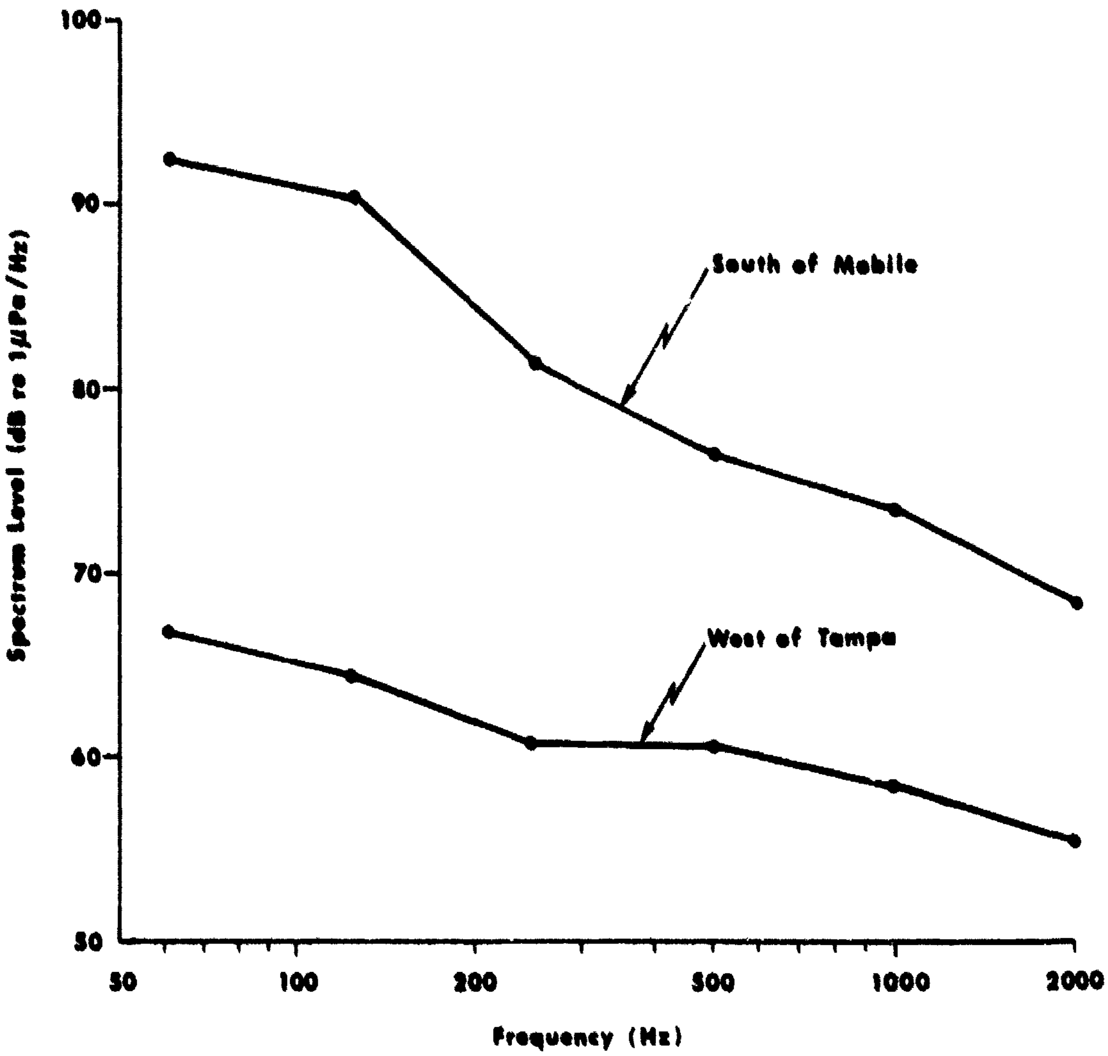


Figure 3-15. (C)Ambient Noise Spectra in Eastern Gulf of Mexico(U)

Reference 16.

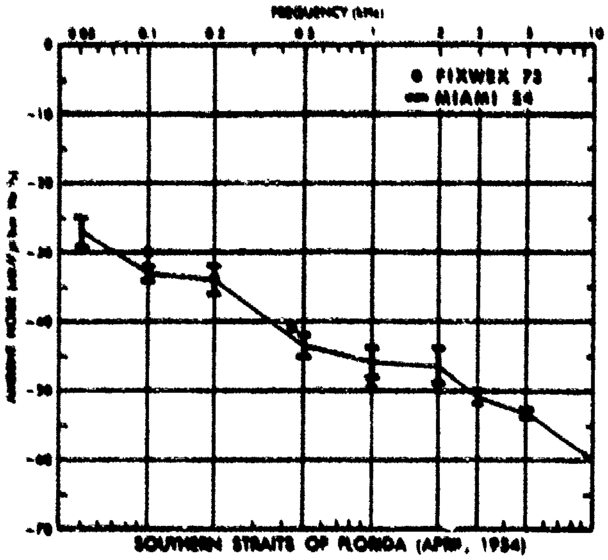


Figure 3-16. Comparative Ambient Noise Spectra, Southern Straits of Florida. References 26 and 30.

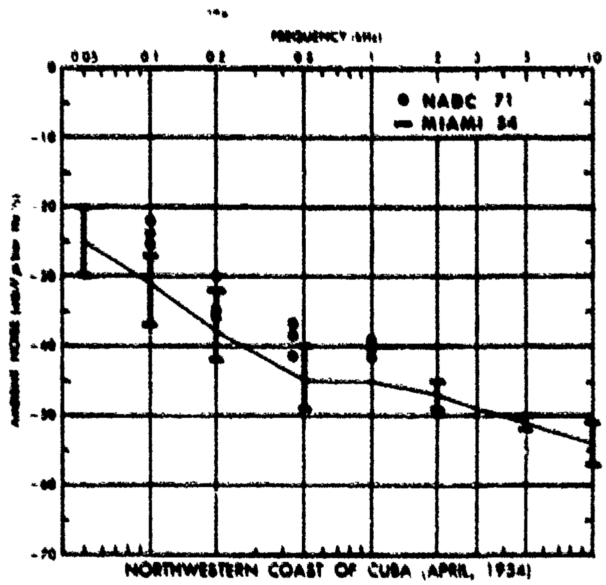


Figure 3-17. Comparative Ambient Noise Spectra, Northwestern Coast of Cuba. References 23 and 30.

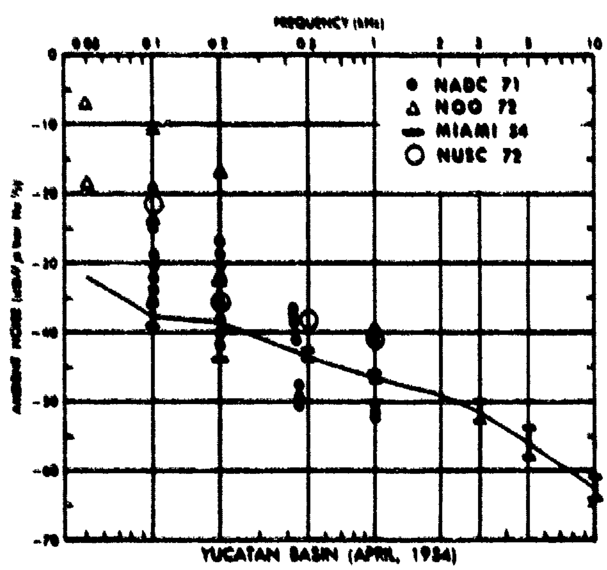


Figure 3-18. Comparative Ambient Noise Spectra, Yucatan Basin. References 15, 23, 28 and 30.

(C)

Navy during a FIXWEX exercise. Both are short data sets. It is noteworthy how well they agree in level throughout the spectrum, although 19 years elapsed between the measurements.

(C) Northwest Coast of Cuba. Noise measurements were made off the northwest coast of Cuba, in the vicinity of the northern entrance to the Yucatan Channel. Measurements were made in the area both by the University of Miami in 1954 and NADC in August 1971 (Reference 23). The noise spectra are shown in Figure 3-17. The more recent spectra are noisier than the older ones by approximately 9 dB at 100 Hz, decreasing to 5 dB noisier at 1000 Hz.

3.2.2.2 (C) Yucatan Basin (U). Noise measurements were made in the Yucatan Basin by the University of Miami in 1954, NADC in 1971, NAVOCEANO in 1972, and NUSC/NL in 1972 (References 22, 23, 15 and 28, respectively). Figure 3-18 compares data obtained from these measurements. The NADC data show a large range of levels, approximately 20 dB at 100 Hz, decreasing to 12 dB at 1000 Hz. The data show the impact of shipping on the noise levels in the areas. The NAVOCEANO data consist of two measurements, one is very high, and the other is equivalent to the higher values measured by NADC and is similar to the NUSC data.

(C) NUSC/NL made measurements using Autobuoy in the northern part of the Basin during Project KIWI. Figure 3-19 shows data obtained from a single dive. Again the noise does not appear to have any significant depth dependence.

3.2.2.3. (C) Cayman Trough Area (U). Extensive measurements were made in the Cayman Trough area during the CHURCH GABBRO Exercise in November and December 1972. Reference 15 contains a detailed description of the data acquired and processed during the Exercise. The main measurement tools employed during the CHURCH GABBRO Exercise were two ACODACs, deployed at two sites both shown as location 15 on Figure 3-11. The western site was

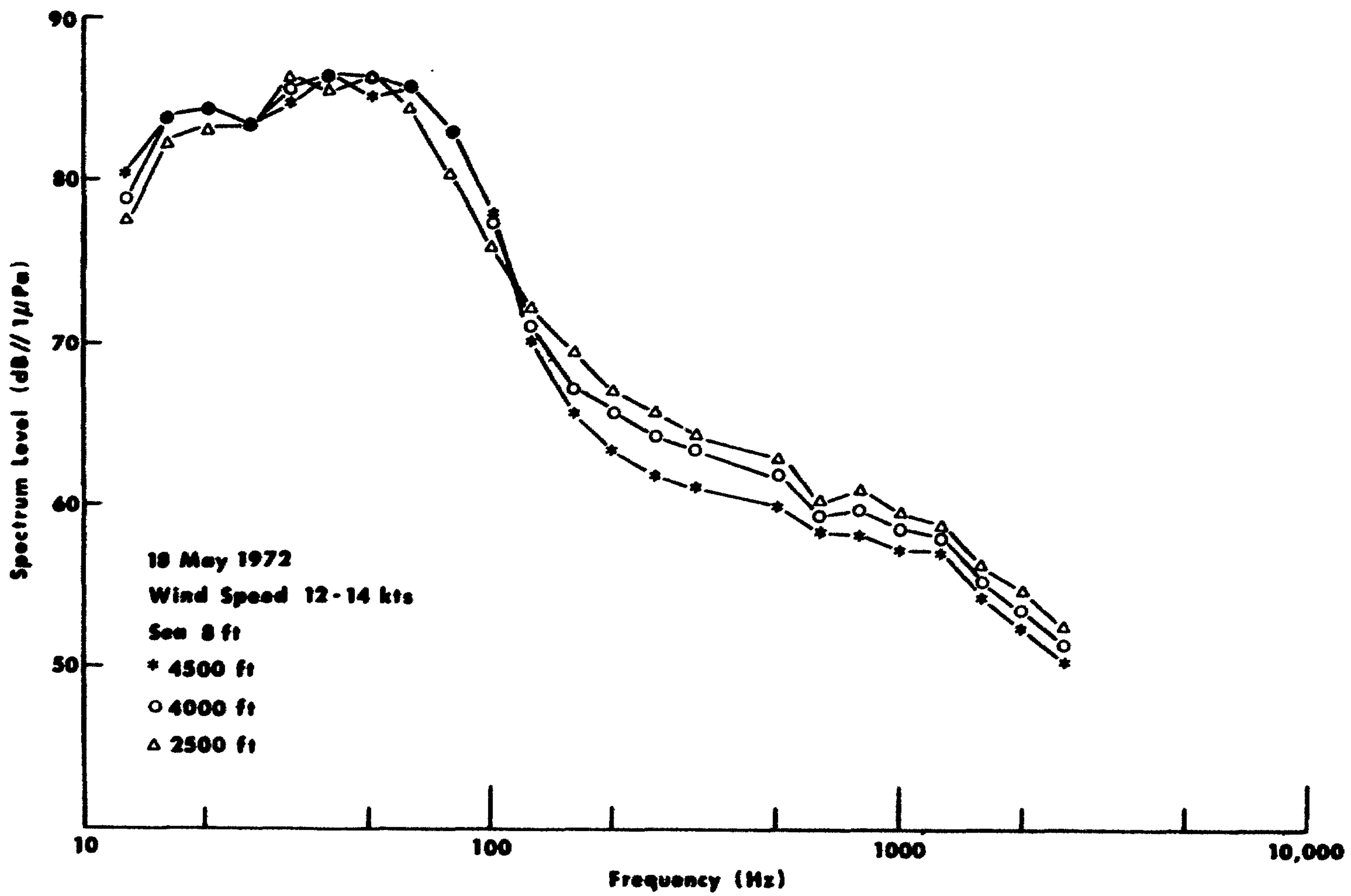


Figure 3-19. (U) Ambient Noise Spectra from KIWI in Yucatan Basin. ‑)

Reference 28.

(C)

designated Position D and the eastern one Position B. Figures 3-20 through 3-23 show the depth dependence of the mean acoustic levels for 25, 50, 100 and 200 Hz. The mean level of the noise is nearly constant with depth, but the variance is very high and is a function of both site and depth. Details are provided in Reference 15.

(C) Reference 13 discusses ambient noise fluctuations at some length. The large fluctuations in the Cayman Trough area are attributed to the isolation of the Trough from noise sources at long ranges outside the Trough area. This observation indicates that the Trough area is essentially isolated by bathymetric features - the Cayman Ridge on the north, the Nicaraguan Rise on the south, and the sill in the Windward Passage on the east. Reference 15 contains ambient noise statistics in the Trough area.

(C) The Cayman Trough shows a strong horizontal noise gradient, 4.2 dB quieter at Site D in the west than at Site B near the middle of the Trough. MABS was located farther east (location 29 in Figure 3-11). The MABS data yielded levels from one hydrophone at a depth of 128 m. Levels from this sensor indicate that the gradient to the eastward continues; MABS data averaged 4.1 dB noisier than the ACODAC at Site B. Thus the total increase in level from the southwestern end of the Trough to the eastern area where MABS was located was 8.3 dB.

(C) Sonobuoy data were gathered by NAVOCEANO in the vicinity of the ACODAC at the southwestern end of the Trough. Figures 3-20 through 3-23 also show the spread of this data as compared to the nearby ACODAC (Site D). Figure 3-24 shows comparative levels between MABS in 1972, and sonobuoy data acquired by NADC in 1971 and by NAVOCEANO in 1972 (References 15 and 23). The levels are, in general, very high; at 100 Hz and above the data are very consistent, while at 25 and 50 Hz there is a variation of 10 dB.

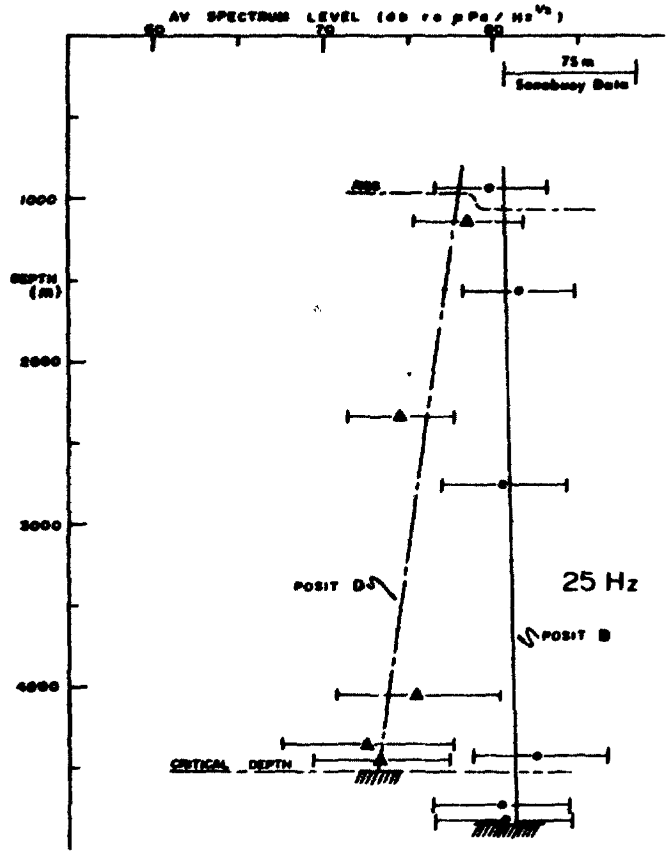


Figure 3-20. (C)CHURCH GABBRO Depth Dependence of Mean Levels, Positions D and B, Including Nearby Sonobuoy Data, 25 Hz(U).

Reference 15.

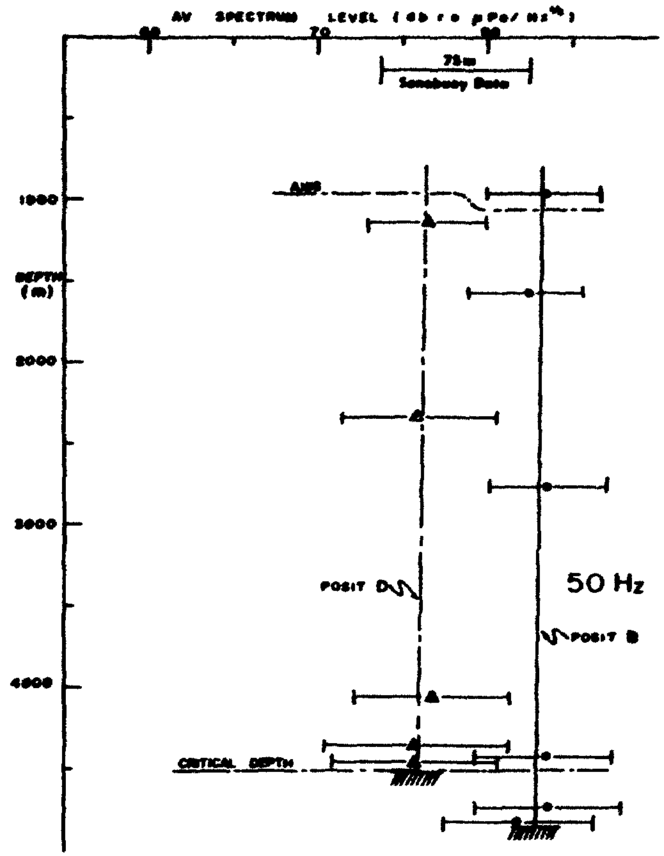


Figure 3-21. (C)CHURCH GABBRO Depth Dependence of Mean Levels, Positions D and B, Including Nearby Sonobuoy Data, 50 Hz(U).

Reference 15.

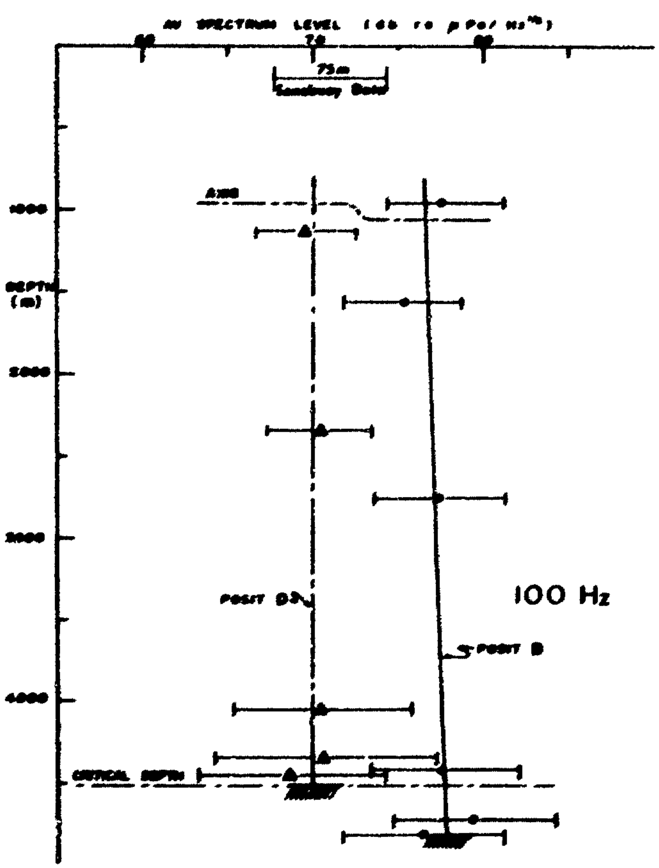


Figure 3-22. (C)CHURCH GABBRO Depth Dependence of Mean Levels, Positions D and B, Including Nearby Sonobuoy Data, 100 Hz(U).

Reference 15.

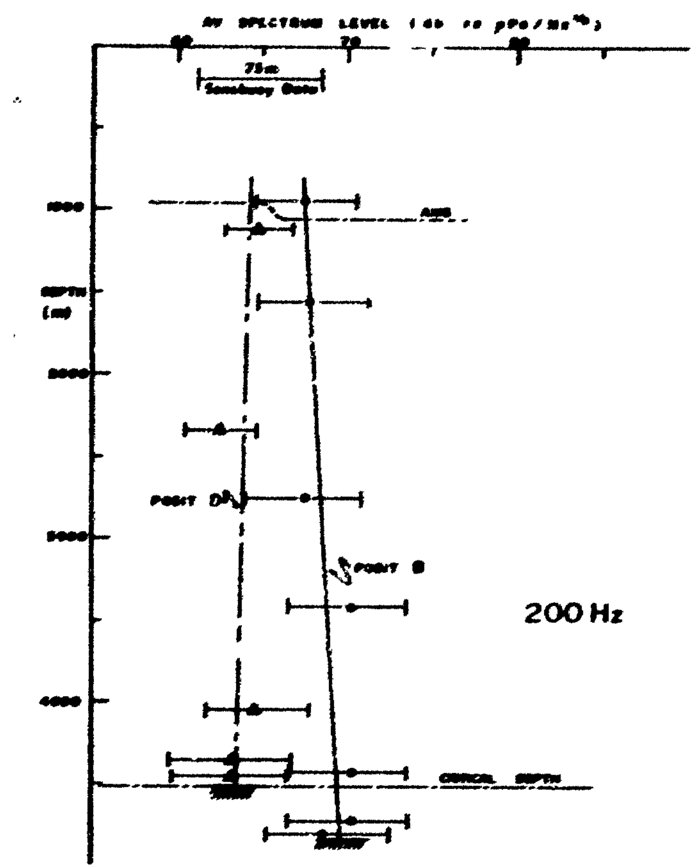


Figure 3-23. (C)CHURCH GABBRO Depth Dependence of Mean Levels, Positions D and B, Including Nearby Sonobuoy Data, 200 Hz(U).

Reference 15.

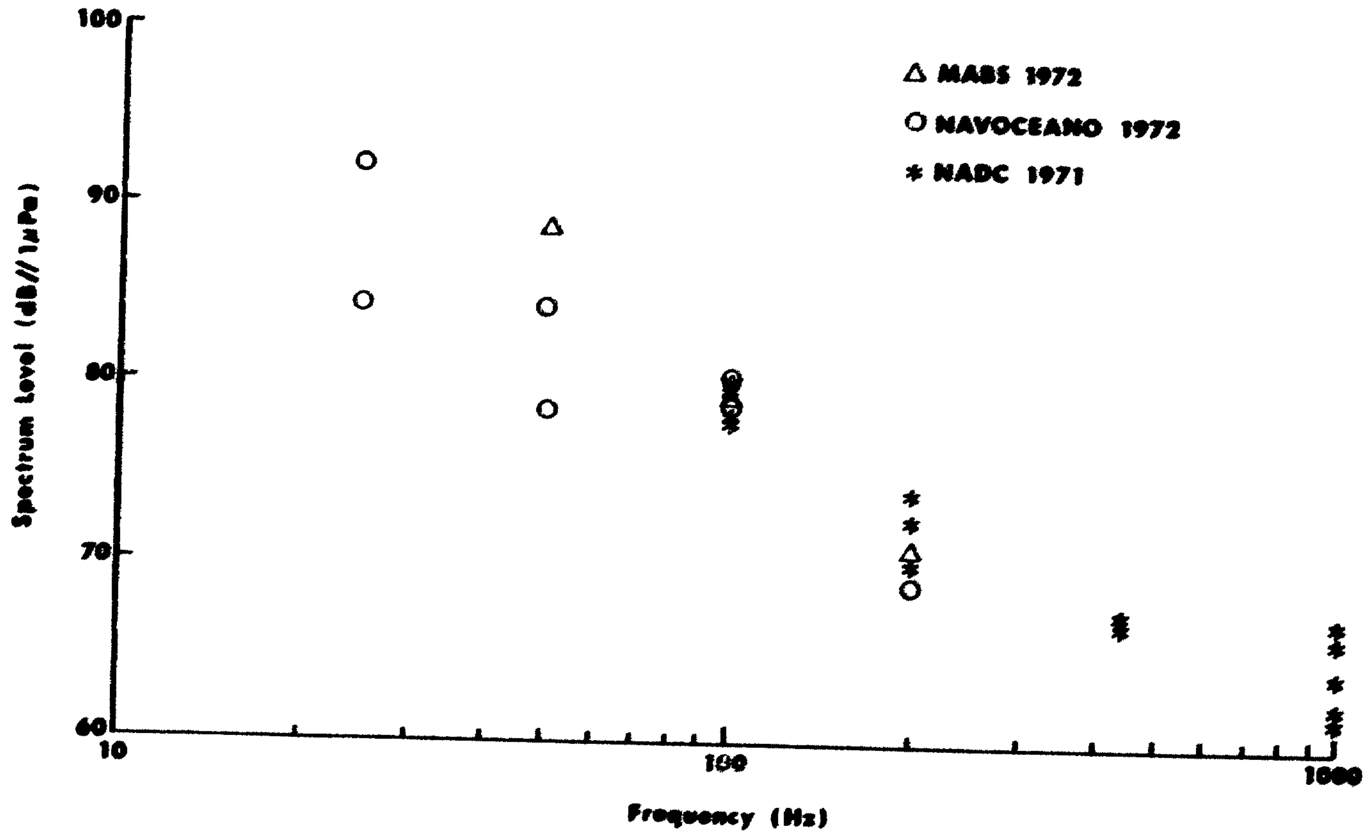


Figure 3-24 (U) Comparison of MABS and Sonobuoy Data for Eastern End of Cayman Trough. (U)

References 15 and 23.

(U) Figure 3-25 shows an historical comparison of noise levels in this area. ACODAC data acquired during the CHURCH GABBRO exercise show an increase in noise level of approximately 10 dB over the University of Miami data gathered 18 years earlier.

3.2.3 (C) Directional Noise Measurements (U)

(C) Vertical noise directionality measurements were made by NADC using VLAM at a nominal depth of 2800 m, at a site shown in Figure 3-11 as location 13, 14. The data were processed by both NUC (NOSC) and NADC (References 13 and 14). The processing by NUC included frequency vs declination/elevation angle, power vs angle, and power spectra for two channels. The outstanding feature of the vertical directionality of the noise field in the Cayman Trough is its variability in level with time at various elevation/depression angles. This variability is attributed to a few ships within the Trough affecting the noise level and directionality. The high intensity noise spikes appear to vary in intensity and angle with time. If we assume that the power spectra for the single element channels are referenced to 1 μbar, the noise levels are very high compared to other measurements in the area.

(U) Figures 3-26 and 3-27 show a typical beam power vs frequency plot from Reference 30 for twenty-three steering angles. Figure 3-26 shows the directionality during a high sea state, and Figure 3-27 illustrates a low sea state.

(U) The omnidirectional noise level measured by VLAM was calculated to within 0.7 dB using the RANDI noise model (Reference 13). The vertical directionalities computed by the model were in general agreement with the measured directionality. From a comparison of the experimental data and modeling inputs, the conclusion was reached that only ships within 200 nm contributed significantly to the total noise.

(U) No horizontal directionality measurements have been made.

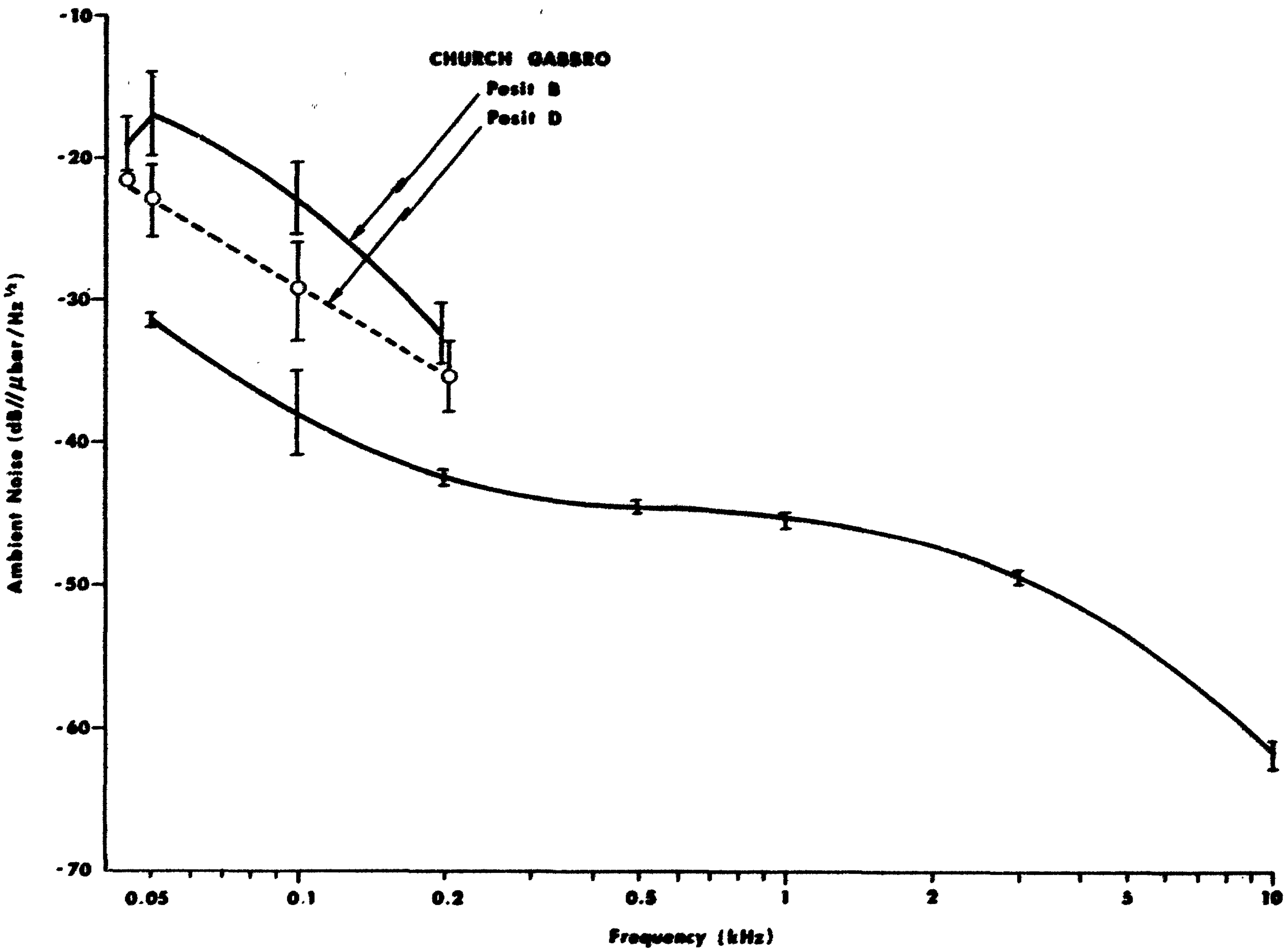


Figure 3-25. (C)CHURCH GABBRO ACODAC Comparison to Previous Results in Cayman Trough of April 1954(U).

References 15 and 80.

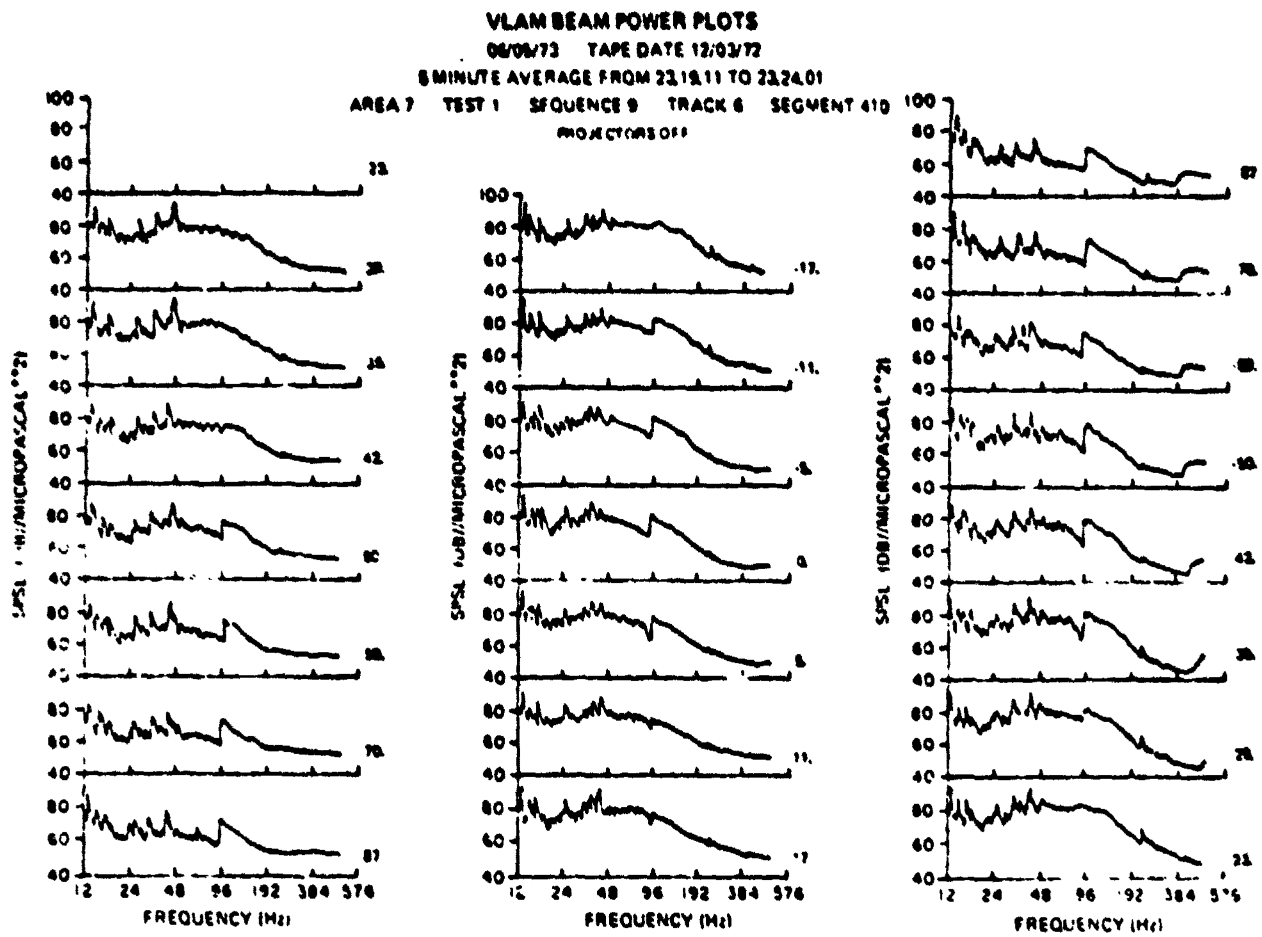


Figure 3-26. (C)VLAM Beam Power Plots(U).

Reference 14.

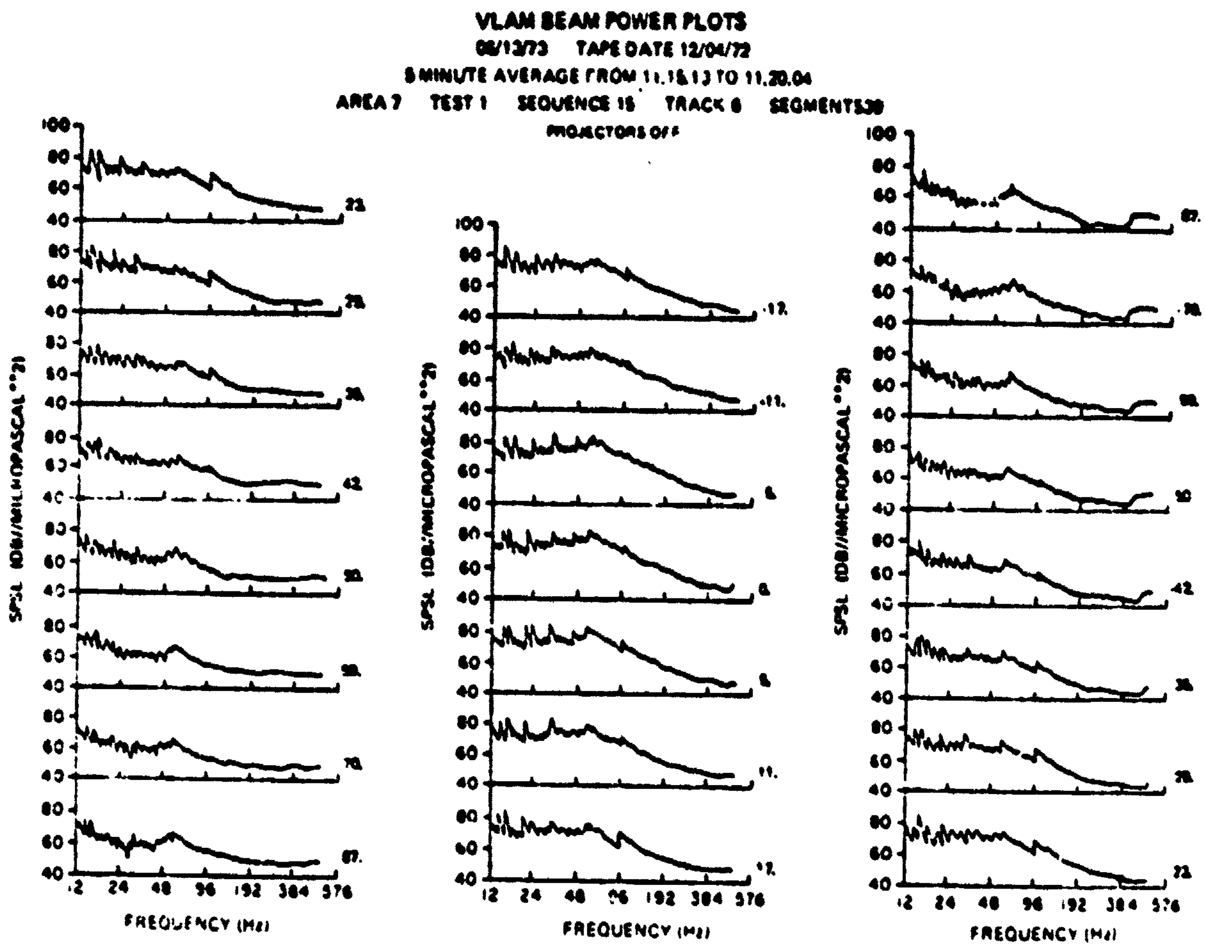


Figure 3-27. (C)VLAM Beam Power Plots(U).

Reference 14.

3.2.4 (C) Adequacy of the Data to Describe the Environment (U)

(C) The available data provide a good phenomenological description of large parts of the region. However, except for the comparison already cited, comparison of data and models cannot readily be made. This arises from either or both the lack of detailed knowledge of the location of noise sources when the experiment was performed and the topographical complexity of parts of the region. The following comments are made to identify data deficiencies and to indicate some of the modeling problems in this area.

1. No data have been located in the western Gulf.

2. In the eastern Gulf the available data are located either on the continental shelf or close to the continental slope. Data at these locations are marginal for modeling purposes because of the difficult signal propagation environment.

3. Data from the southern Straits of Florida indicate very quiet conditions, yet the shipping lanes are close to the FIXWEX measurement site. Further investigation would appear to be warranted.

4. Data from the Yucatan Channel and the northwest coast of Cuba show increasing noise levels over nearly two decades, which one would expect. The data appear to be representative for depths of less than 100 m.

5. Data from the Yucatan Basin appear consistent between the several data sets and also as a function of history. Nearby shipping appears to control the higher noise levels. For this area the data are considered adequate.

6. Data from the Cayman Trough are extensive and indicate three rather startling features:

   a. An 8 db horizontal noise gradient increasing from west to east.
   b. A large temporal variance in noise level.

(C)

c. The temporal variances as a function of depth differ between locations.

From an ambient noise viewpoint the area appears to be very complicated. The large variability has been attributed to a small number of ships contributing to the ambient noise because of bathymetric blockages.

7. The adequacy of omnidirectional noise measurements as a function of depth is marginal, being represented by data from four locations. The KIWI measurement in the Gulf shows no depth dependence, yet downslope conversion is predicted and high noise levels are expected near the channel axis. The lack of depth dependence is attributed to the site being close to the shipping lanes. Depth-dependent measurements outside the shipping lanes in both the western and eastern Gulf are needed to investigate the predicted depth dependence.

8. The data from the single site in the Yucatan Basin are probably adequate.

9. The data from the two sites in the Cayman Trough are inconsistent with regard to fluctuation variance as a function of depth. Also the depth variation is different from that observed in the Atlantic. These differences are probably caused by the small basin environment.

10. There are no vertical directionality measurements with the exception of one set of data in the Cayman Trough. That data set shows great temporal variability, as do the other

(C)

data from the Trough. Unless a thorough examinaton of the acoustic properties of the Trough is intended, further directionality measurements will only further document the variability.

11. There are no horizontal directionality measurements.

3.2.5 (C) Recommendations for CHURCH STROKE III (U)

(C) All types of noise data are needed in the Gulf of Mexico, especially in the Sigsbee Deep and its extension to the Straits of Florida. Long term omnidirectional noise and its change as a function of depth should be a high priority goal. Because the petroleum industry is expected to have a high impact on the noise level as a function of depth and direction, the horizontal directionality of the noise as a function of depth should also be addressed. A set of near-surface measurements covering most of the Gulf should be made to define any lateral pattern of noise level gradients such as was observed in the Cayman Trough area.

(C) Because of the high ship traffic at the entrances to the Gulf, both temporal and spectral noise level statistics as a function of depth should be measured. Adequate noise characterization can be obtained from such measurements.

(C) Measurements in the Yucatan Basin should be made to confirm the historical noise level trend. Long term temporal and spectral statistics would be useful for assessment purposes.

(C) A large amount of data has been collected for the Cayman Trough area. The data indicate large temporal and depth variations. Measurements to identify the cause of these variations would be useful but are probably not necessary for assessment purposes.

3.3 (C) Petroleum Industry Impact (U)

R. Hecht
Underwater Systems, Inc.

(U) The continental shelf off the Gulf of Mexico produces more petroleum than any other offshore region in the world. The drill rigs that drill exploration wells, production platforms that drill developmental wells and support oil and gas production, and seismic profilers and support boats, are noise sources that contribute to the overall noise level budget of the region. The effect of these noise sources on the overall ambient noise level in the region is dependent on the propagation loss from these noise sources to locations where the ambient noise level is of interest.

(U) Figure 3-28 shows the location of petroleum activity in the CHURCH STROKE III Exercise region. Offshore activity in the United States is confined to the state and federal waters of the states of Louisiana and Texas. The shaded area south of Texas and Louisiana (T-LA) shows the locations of over 780 production platforms in federal waters and the dots represent single, isolated platforms (Reference 33). The distribution of the platforms delineates the major area of constant noise due to the petroleum industry.

(U) Production and development activity in Mexico is confined to the Marine Golden Lane (the seaward portion of the Golden Lane Atoll) and the Bay of Campeche field. There are approximately 15 production platforms in the Marine Golden Lane region (Reference 33). The Campeche field is in the exploration-development stage, with 2 production platforms on order (Reference 34). Petroleos Mexicanos (PEMEX) has stated that development is initially confined to water depths of less than 446 ft and possibily 180 ft.

(U) Movable noise sources from the petroleum industry consist of mobile oil rigs and seismic profilers. The mobile rigs perform such functions as drilling a stratigraphic test, a wildcat well and pool

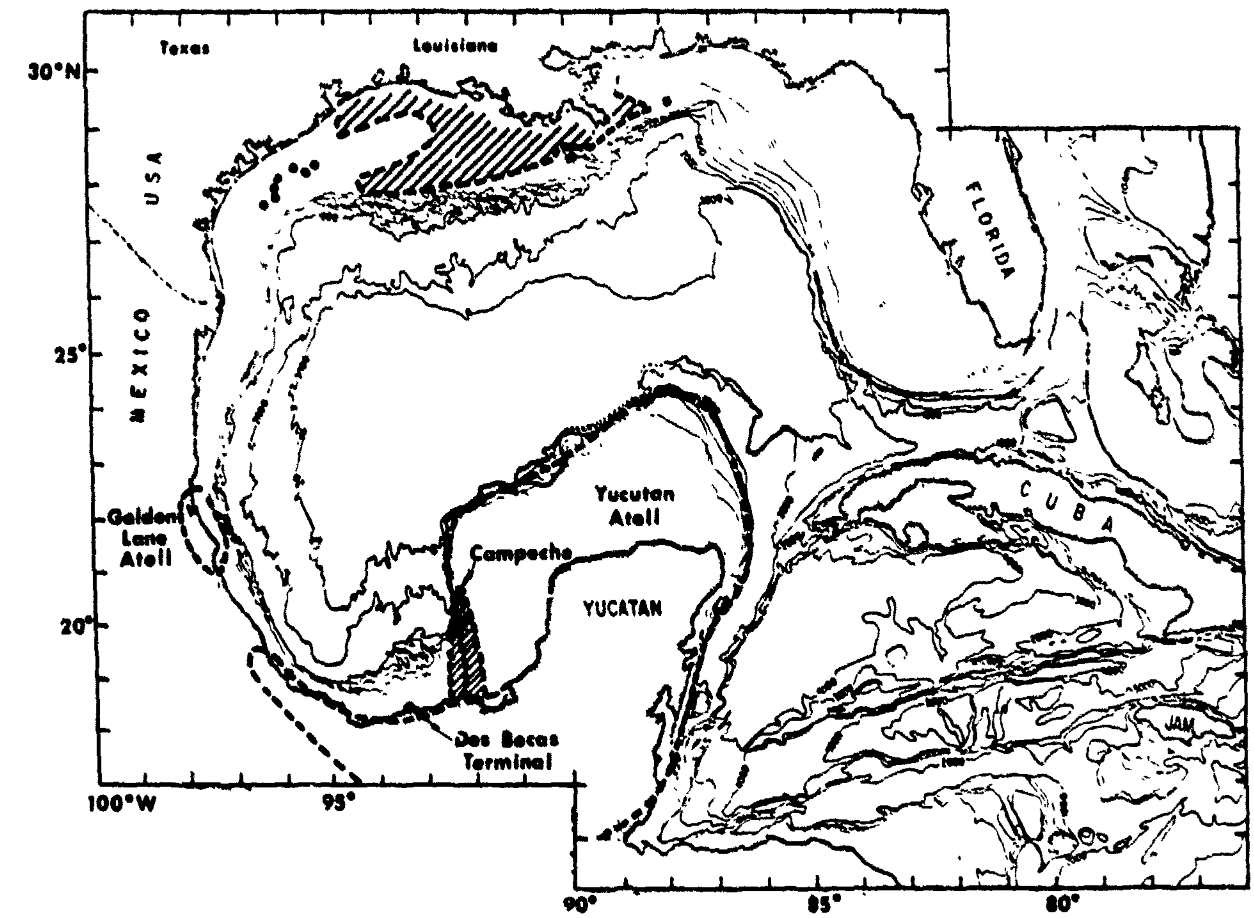


Figure 3-28. Location of Production Platforms, Campeche Oil Fields, and Geologic Atolls. (U)

(U)

delineation wells. The 100 or so rigs in the T-LA area will be distributed along the shelf and slope in water less than 2,000 ft deep, which is the normal maximum drilling depth. The rigs move from site to site, and the time to drill a hole varies from about a day to several months. Exploration and development of the Golden Lane has been halted in favor of the more promising Campeche region, and nine offshore rigs in Mexico are now exploring and developing the Bay of Campeche and related stratigraphic structures (Reference 35).

(U) Seismic profilers can be expected to range the entire petroleum production area as well as potential petroleum production areas. We can expect ten profilers to be operating in the T-LA region at any one time. The operations are not continuous, being interrupted by transit times and bracketed by exploration objectives. The profilers can be expected to operate on the shelf and slope using sparkers, sleeve exploders, air guns, and chemical explosives as seismic sources. During 1978 two profilers explored the western side of the Yucatan Atoll to define the structural features of the Bay of Campeche area, as well as the northern and eastern extensions of the Yucatan Atoll (Reference 36). Exploration for petroleum is also being performed on the shelf of Belize (an extension of the reef that forms the stratigraphic horizon of the Campeche field petroleum area), and on the coastal shelves off Honduras and Nicaragua. Exploration activity in these areas has generally been at a low level.

(U) Another source of noise is the support boats that tow the rigs and supply the production platforms and rigs. There are approximately 1,200 such boats that belong to corporations located in the T-LA region (Reference 37).

(U) For the CHURCH STROKE III Exercise, the overall impact of all the noise sources outlined above is totally dependent on the propagation loss from the region of production activity into the deeper basin. The

(U)

majority of activity in the T-LA region takes place at depths of 300 ft or less, and hence poor propagation could minimize noise contributions due to the petroleum industry. On the other hand, if propagation is relatively good on the shelf, then downslope conversion on the slope could result in high level noise in the vicinity of the sound channel axis.

(U) Each of the noise sources - drill rigs, production platforms, support boats and seismic profilers - will be discussed in turn as to their potential effect on the CHURCH STROKE III Exercise. The information has been gathered from the petroleum industry journals and data obtained from measurements on the oil rig SEDCO J off Nova Scotia.

3.3.1 (C) Offshore Drilling Rigs (U)

(U) Mobile oil drilling rigs that are used for offshore prospecting consist of five types: drillships, semisubmersibles, jackups, submersibles, and fixed platform rigs.

(U) A drillship can be likened to a regular cargo ship on which a drilling derrick has been mounted. The prime movers are located in the engine room. The line component radiation from the drilling equipment will be similar to that of an ordinary ship that is utilizing the same horsepower. If the drill rig is anchored in place, no cavitation noise will be generated; otherwise, cavitation noise from the thrusters will be present.

(U) A semisubmersible can be simply described as a deck supported by caissons from submerged pontoons. All of the drilling equipment is on the deck, well above the water. Most of it is mounted on transportable skids, so the complement of equipment can be changed. Because of the caissons, pontoons and support structure, the rig should be visualized as a distributed acoustic source. Approximate dimensions for most semisubmersibles are 250 ft x 275 ft; they are usually ballasted to a pontoon keel depth of 50 to 80 ft. The drillships and semisubmersibles are limited to drilling in water depths that are compatible with the

(U)

equipment on board; an increase in capability of on-board equipment can increase the maximum operational water depth.

(U) Jackup rigs consist of a deck containing the prime movers and drilling machinery, supported by three or more legs. The name is derived from the fact that, after the deck is floated to its desired location, it jacks the legs down to the bottom and the deck above the water surface. The length of the legs determines maximum water operating depth. Maximum known operating water depth is 600 ft; however, most jackup rigs are designed to operate in water depths of 400 ft or less. The jackup rig is a complex sound radiator. The legs are usually open framework truss construction that rest on flat pads on the bottom. The acoustic efficiency of truss type legs at low frequencies is unknown. The mechanical vibrations can be transmitted by the legs to the supporting bottom and then reradiated into the water.

(U) The submersible rig can be viewed as a floating barge that is brought into position and flooded until it rests on the bottom. Submersible rigs are usually used in water depths of 75 ft or less. Although there is no data on the submersible rig as an acoustic radiator, it appears that it should be an efficient radiator in the shallow water environment.

(U) The fixed platform rig is like a land rig that is mounted on skids so that it can be placed on a platform by a derrick or other means. The platforms to hold the rig are generaly constructed of piling and hence are limited to rather shallow water. There are 131 fixed platform rigs in the T-LA region and 10 in the Marine Golden Lane area of Mexico (Reference 35). Since the submersible and fixed platform rigs are used in shallow water of usually less than 100 ft, they will not be further considered in this pre-assessment.

(U) Figure 3-29 shows the number of rigs in the CHURCH STROKE III Exercise area as of July 1978 and their distribution as a function of

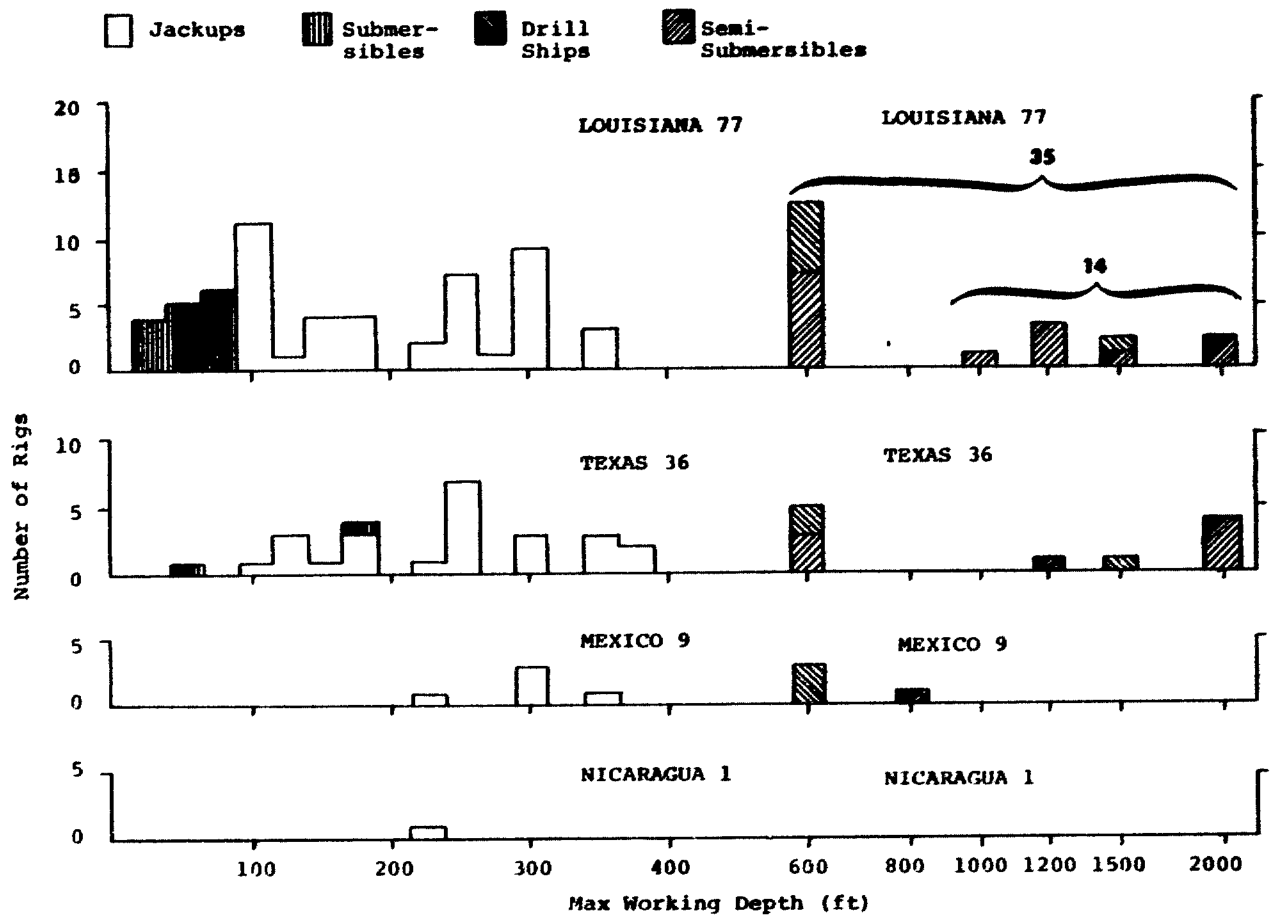


Figure 3-29 (U) Distribution of Offshore Rigs as a Function of Maximum Water Depth Capability. Numbers as of July 1978. (U)

(U)

maximum depth of water in which the rig can drill. There were 113 rigs in the T-LA offshore area, 9 in Mexico's Bay of Campeche, and 1 off Nicaragua (Reference 33). Of the 123 rigs in the Gulf of Mexico, only 35 can operate in water 600 to 2,000 ft or deeper, and only 14 in water 1,000 to 2,000 ft in depth. Thus, if propagation loss on the shelf is high, there will be only a few rigs that will affect the overall noise level. On the other hand, if the propagation loss is low on the shelf, many more will contribute to the overall ambient noise level.

(C) The contribution of the rigs to the ambient noise level is dependent on the source level of the rig. Measurements made by E. E. Davis (NORDA) and R. J. Hecht (USI) indicate that the source level of a semisubmersible rig is similar to that of a large ship. Figures 3-30 and 3-31 show typical spectra from SEDCO J and Western Pacesetter III. Both measurements were made over the side while the rig was drilling. Spectra are characterized by the harmonics of the rotation speed of the prime movers. The levels in the figures are the measured levels at the hydrophone. For SEDCO J the hydrophone was on the bottom under the rig; a 20 log R spreading loss correction of 36 dB added to the measured values will give an indication of source level. The source level of SEDCO J was determined to be 149 dB//μPa at 50 Hz during Project APEX (Reference 39). The Western Pacesetter III measurements were made with a hydrophone suspended over the side; the high level noise in the low frequency region is attributed to cable flutter. As part of the CHURCH STROKE I data analysis, the 30 Hz line from SEDCO J was analyzed in 19 mHz bandwidths. The line was found to be composed of a doublet separated by 0.18 Hz, which is twice the separation observed at 15 Hz (the fundamental). Figure 3-32 shows the doublet and dynamics related to drilling operations as documented on the TOTCO charts (charts that automatically record a number of the operating variables for which there is rig instrumentation). At the time there were two 16-cylinder diesels driving generator sets at

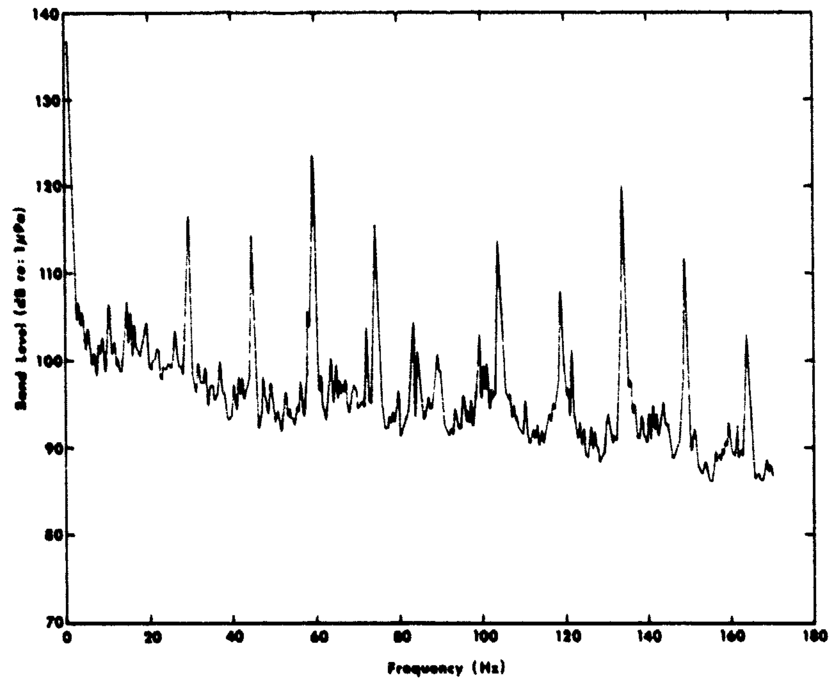


Figure 3-30 Average Band Level as Recorded by the Bottomed Hydrophone at SEDCO J. 19 June 1975, 0839-1009 ADT. Data Base - 1320 4.1-sec Samples. (Reference 38).

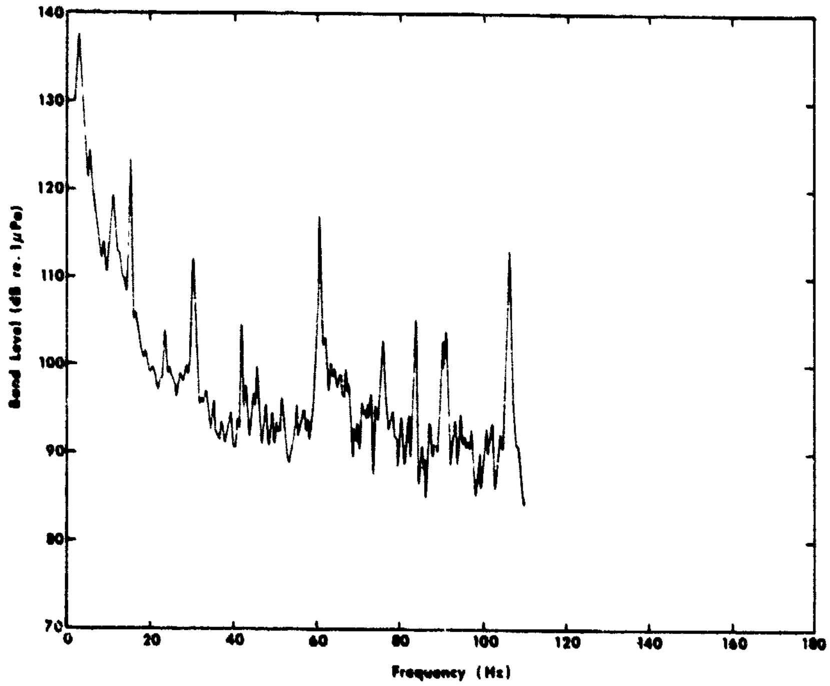


Figure 3-31 Average Band Level as Recorded from a Hydrophone Suspended at the Bow of Western Pacesetter III. 23 February 1975, 1012-1143 CDT. Data Base - 1338 4.1-sec Samples. (Reference 38).

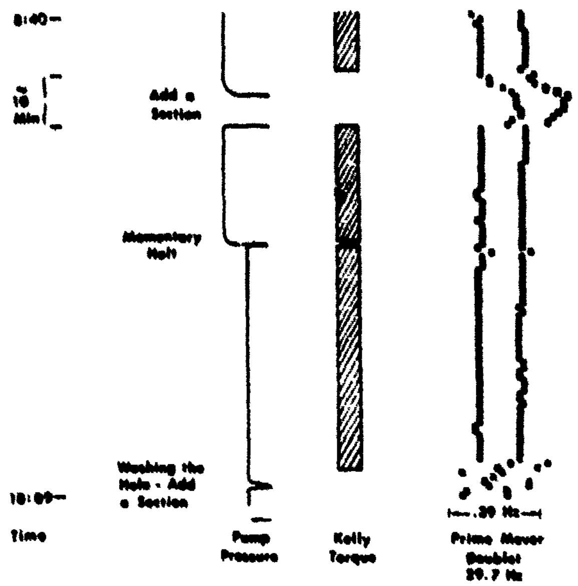


Figure 3-32. Comparison of Drilling Events with Doublet Dynamics

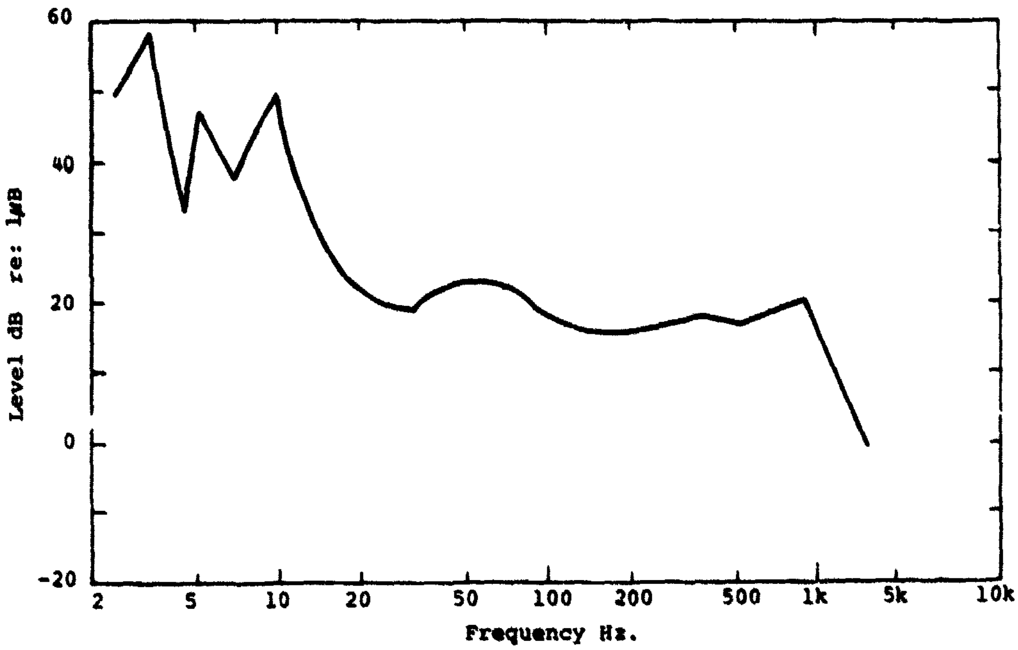


Figure 3-33. Source Level of Stormdrill IV.

(After Reference 40)

(C)

900 rpm. From this analysis it was concluded that semisubmersible oil rigs powered by GMC EMD diesels have a characteristic line structure.

(U) Figure 3-33 shows a radiated noise measurement of STORMDRILL IV furnished to USI by Exxon Corp. The exact conditions of measurement are not known, but they show more low frequency energy than the SEDCO J measurements. In addition the broadband processing has masked the prime mover line components.

(C) The only available data on drillship source level at frequencies between 10 and 150 Hz was obtained during Project APEX. The experiment showed that the source level of the Glomar Challenger was less than 155 dB//μPA at 50 Hz (Reference 39). The Glomar Challenger maintains position by the use of thrusters. Figure 3-34 shows the source spectrum level for a single thruster. These levels are only indicative since the thrusters on the Glomar Challenger are in tunnels. Since the drillships in the Gulf of Mexico will be of somewhat different construction, these levels should be used with caution.

(U) For the CHURCH STROKE III Exercise we can expect about 110 drill rigs to be operating off the T-LA coast that have a source level comparable to a medium-sized merchant ship. As many as 35 rigs can be in water 600 ft or deeper. We can expect 9 rigs to be operating in the Bay of Campeche and possibly 1 off the coast of Belize, Honduras or Nicaragua. The source level information on hand is inadequate for an assessment of the impact of drill rigs on the ambient noise.

(U) The locations of the mobile rigs can be obtained from the U.S. Geological Survey district offices on a daily basis and from the main office in Metairie, Louisiana on a weekly basis.

3.3.2 (U) Production Platforms (U)

(U) Production platforms are installed to drill developmental wells, to produce the petroleum, and to maintain the wells. The platforms have a

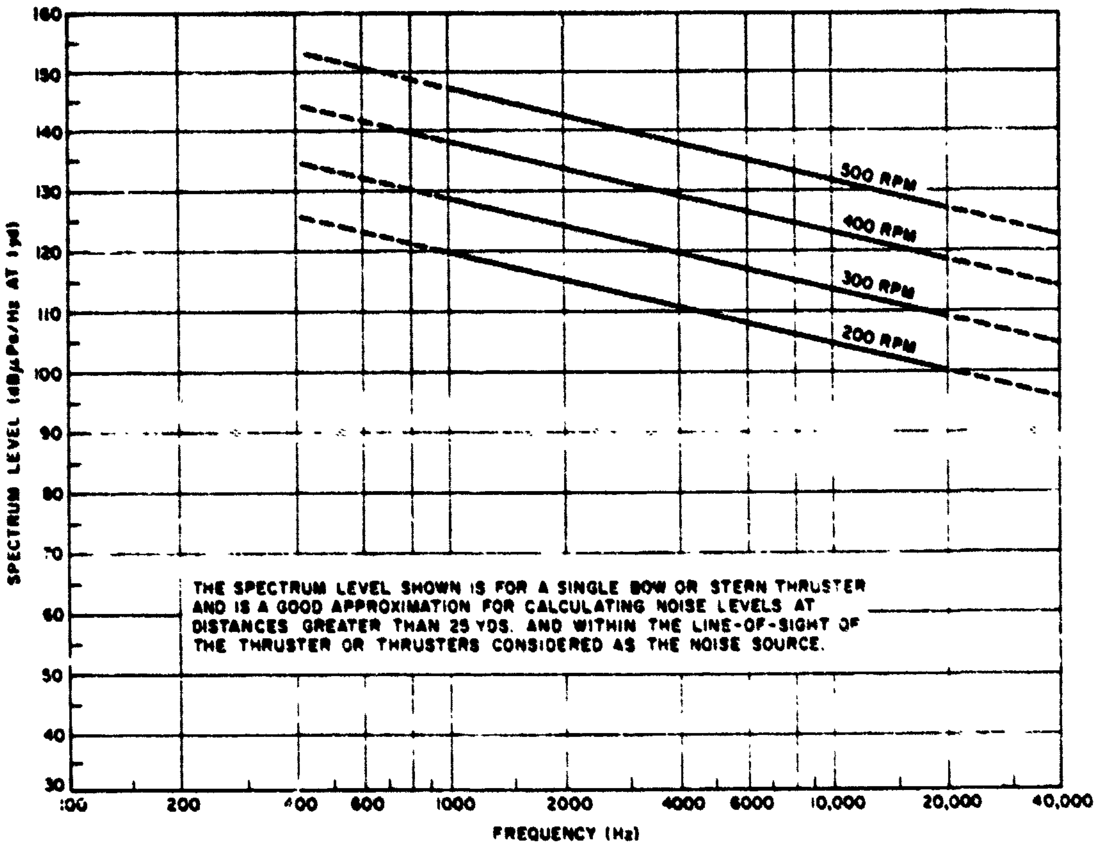


Figure 3-34. (U) Approximate Spectrum of Equivalent Glomar Challenger Thruster Noise Source. (U)

(From Reference 39).

(U)

drill rig aboard or a place for a fixed platform rig, pumping equipment, and usually a large air compressor and living quarters. The platforms rest on legs on the bottom and are similar to a jackup rig except that they are permanent structures.

(U) The number of active multi-well platforms in U.S. federal waters is listed as 604 as of January 1, 1978 (Reference 33). This number includes platforms that have 6 or more wells. The number in Mexican waters is listed as 15. Although producible oil has been discovered in Nicaragua, no platforms are listed.

(U) Active structures in the Gulf of Mexico number 2,233 (Reference 34), which is considerably larger than the 604 production platforms noted above. The difference results from the definition used in the count. Offshore structures include well protectors, single-well platforms, navigation structures, and production structures which range in size from 1 to 60 wells. Reference 33 contains a map of the federal waters of the T-LA region on which platforms and single-well structures are plotted. A count from this map indicates 787 platforms in federal waters. The accuracy of the number can be affected by interpretation of overprinted symbols. Single-well structures appear to be limited to the shallower water depths (seldom exceeding 180 ft).

(U) Of the platforms being constructed during 1978, 19 out of 113 have fewer than 6 well slots, and the 19 are to be used in water depths of less than 100 ft. Therefore, it appears that there is considerable variation in the count of offshore structures, especially in shallower waters. The count of 168 platforms in deeper water (>180 ft) is believed to be fairly accurate.

(U) Figure 3-35 shows the distribution of platforms under construction as a function of their designed installation water depth (Reference 34). Despite the increase in deep water exploration, most of

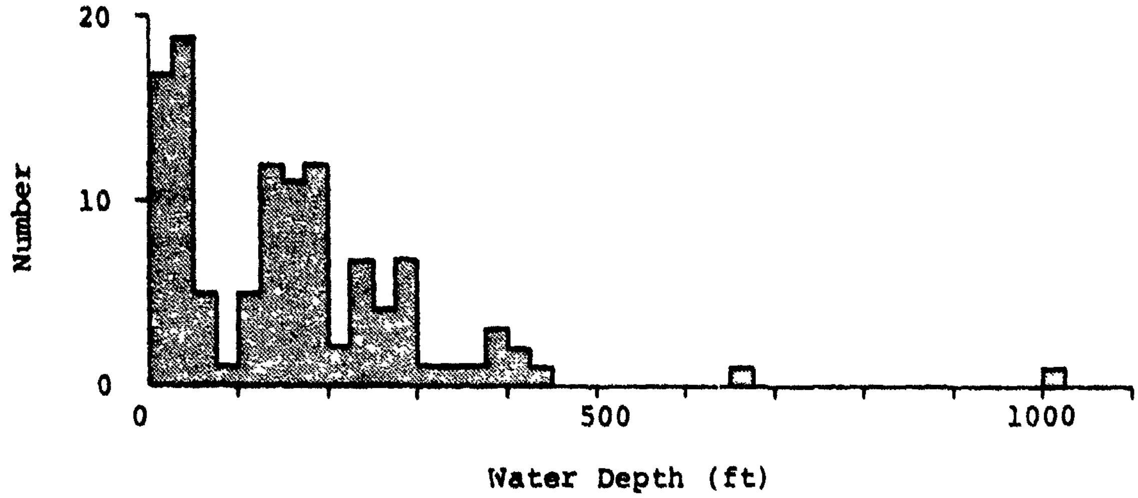


Figure 3-35.(U)Number of Production Platforms on Order and in Various Stages of Installation for Each 25 ft Water Depth Class. Texas - Louisiana Offshore Region. (U)

(After Reference 34).

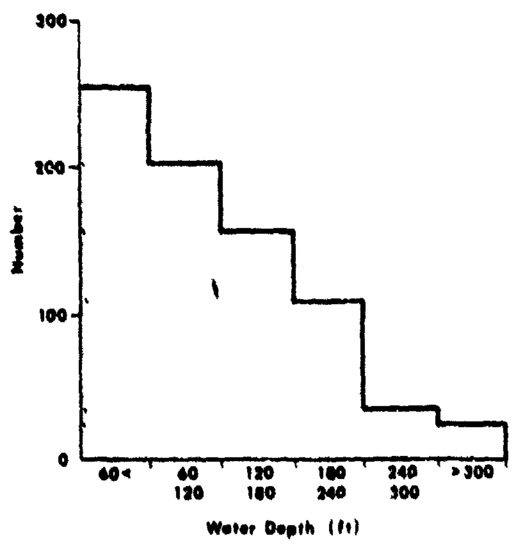


Figure 3-36.(U) Number of Multiwell Production Platforms in Federal Waters of Texas - Louisiana by 60 ft Water Depth Class. (U)

(Reference 33).

(U)

the activity is apparently taking place in the shallower water depths. Although Mexico has deep water reserves, PEMEX is developing the fields under shallow water first.

(U) Figure 3-36 shows the distribution of multi-well platforms as a function of water depth. There are only 60 platforms in water deeper than 240 ft that can potentially contribute to the ambient noise, if sound propagation is poor in the shallower water.

(U) No information has been located on the positions of 15 multi-well platforms in Mexico. One surmises from petroleum literature that most, if not all, are located in the Marine Golden Lane area and at least 1 is probably in water 150 ft deep.

(U) The source level for production platforms is anticipated to be about the same as for a jackup rig. There are no known measurements.

3.3.3 (U) Support Boats (U)

(U) The installation, movement and supply of offshore rigs and platforms requires a large number of boats of different capabilities. A listing of the support craft for companies located in Texas, Louisiana, Mississippi, Alabama and the Gulf side of Florida indicate 1,200 craft ranging from 25 to 225 ft in length (Reference 37). Figure 3-37 shows the propulsion horsepower distribution among the 1,200 craft. From a noise contribution standpoint, the question is, "How many boats are towing or transiting at a given time?"

(U) A comparison between the rated horsepower of mobile rigs and the supply boats shows that a majority of the supply boats utilize about the same horsepower as a mobile rig. While aboard SEDCO J, it was observed that approximately 1,000 kVA or 1,340 hp was required to run the entire rig while drilling. Power usage on Western Pacesetter III did not appear to be much different, because the rig was operated for a short period with a single 2,150 hp GMC EMD capable of generating 1,500 kVA. From this

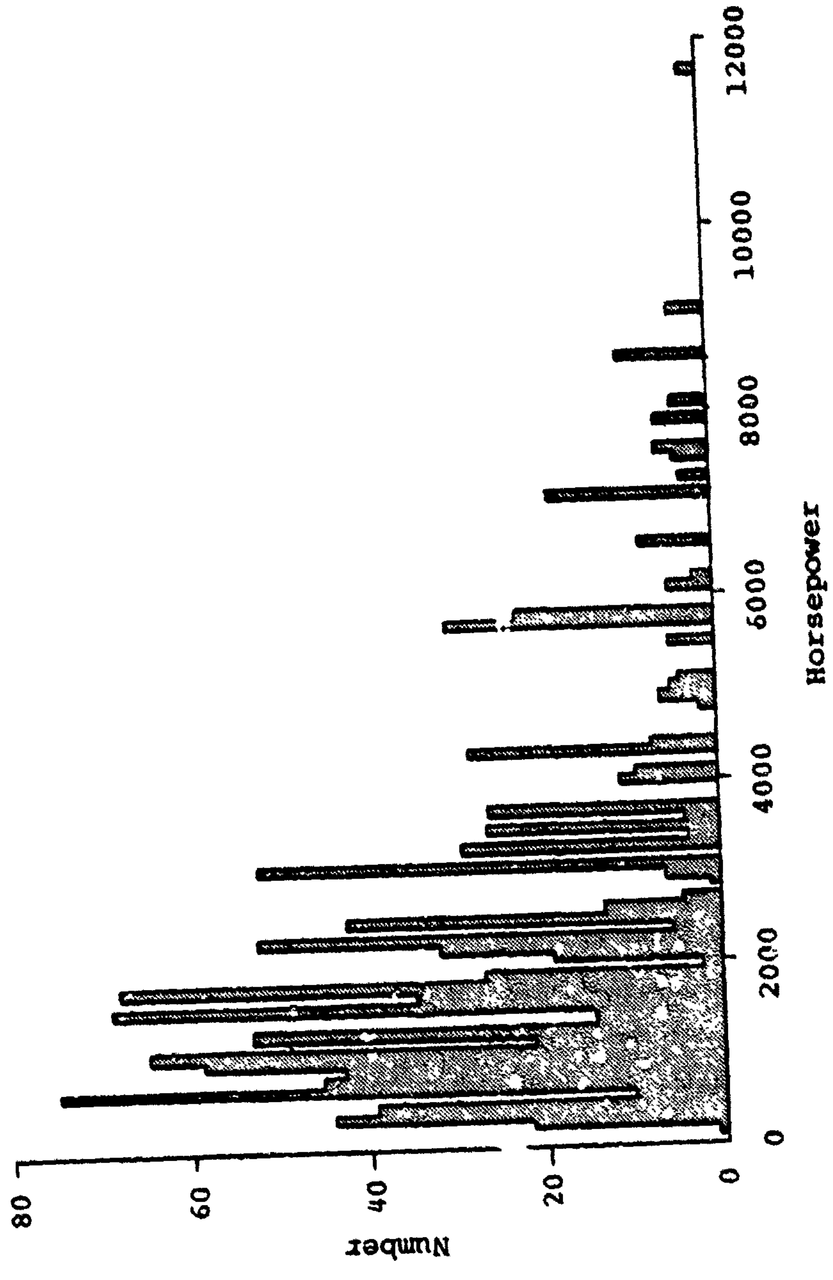


Figure 3-37. (U) Number of Support Vessels per 100 Hp Class Owned by U.S. Companies in Gulf of Mexico Area. (U)

(After Reference 37).

(U)

observation one concludes that about 40% of the support boats generate as much power while working as the rigs do while drilling.

(U) The support boats that are operating will be in the T-LA region, chiefly in the region of the production platforms shown in Figure 3-28. There will be some outside this area servicing the mobile rigs.

(U) The Mexican offshore petroleum industry is much smaller than the T-LA industry. Since the Marine Golden Lane has offshore production wells, we can anticipate that a number of support craft operate in that area. The Bay of Campeche is presently being explored by 9 rigs, so we can expect about that number of supply boats to be operating there at all times. PEMEX is planning to build a large terminal at Dos Bocas for shipping petroleum from the Reforma and Bay of Campeche areas. Once the construction begins, we can expect increased ship traffic to that terminal.

3.3.4 (U) Seismic Profilers (U)

(U) Seismic profilers are used by the petroleum industry to gather information on buried geologic structures in which oil or gas could potentially be trapped. A profiler consists of a ship that tows a long line array of hydrophones usually several thousand feet long, and a source that emits a high level impulse. The ship proceeds at a slow speed along predetermined tracks and records acoustic reflections from geologic strata as received by the array. There are four types of high level impulsive sources: sparker, sleeve exploder, air gun, and chemical explosives. Explosives are usually not used because of environmental restrictions, safety restrictions, and cost. The sources are towed from the profiler ship at a depth of 5 to 50 m, the depth depending on the effect desired from the air-water interface. These sources can cycle at a repetition rate of 5 to 30 seconds, depending on numerous factors.

(U) A survey of the available seismic profilers was made in 1976 and the type source and the normal peak level output were tabulated (Reference 41). Figure 3-38 shows the number of profilers with the same peak level output. The sources are usually configured in arrays to achieve maximum level in the downward direction and to control the sidelobes as necessary. It is estimated that the peak pressure level is 12 dB higher in the downward direction than in horizontal directions (Reference 41). The 231 dB//μPa level is obtained from a sparker and is used by Decca Navigation Co. The 241 dB//μPa level is obtained from an array of sleeve exploders and is used by Western Geophysical, Inc. The 252 dB//μPa is obtained from an air gun array and is used by Geophysical Services, Inc. It is estimated that there are 10 profilers constantly engaged in exploration work in the northern Gulf of Mexico, and PEMEX is reportedly using 2 in the vicinity of the Bay of Campeche and the periphery of the Yucatan Atoll. With this number of profilers and the high source levels, the ambient noise levels in the Gulf of Mexico could attain a high level unless the propagation loss is very large. Since the profiler activity could affect the planned CHURCH STROKE III Exercise, the impact of profiler sources on the noise levels should be examined in some detail.

<u>(U) Air Guns (U)</u>

(U) The air gun derives its impulsive signal from releasing a volume of air under high pressure into the water. Figure 3-39 shows a typical pressure-time trace of a 24-gun air gun array. The array shapes the output pulse to minimize the bubble pulse effects. The length of the resultant pulse is approximtely 50 ms. The resultant spectrum is also shown. The relative power spectrum was converted to a peak spectral level by dividing the peak level (PL) by the area under the spectral curve. This is equivalent to the PL $-$ 10 log BW_{corr} or 252 dB $-$ 15.2 dB $=$ 237 dB//μPa for the 0 dB ordinate on the relative curve.

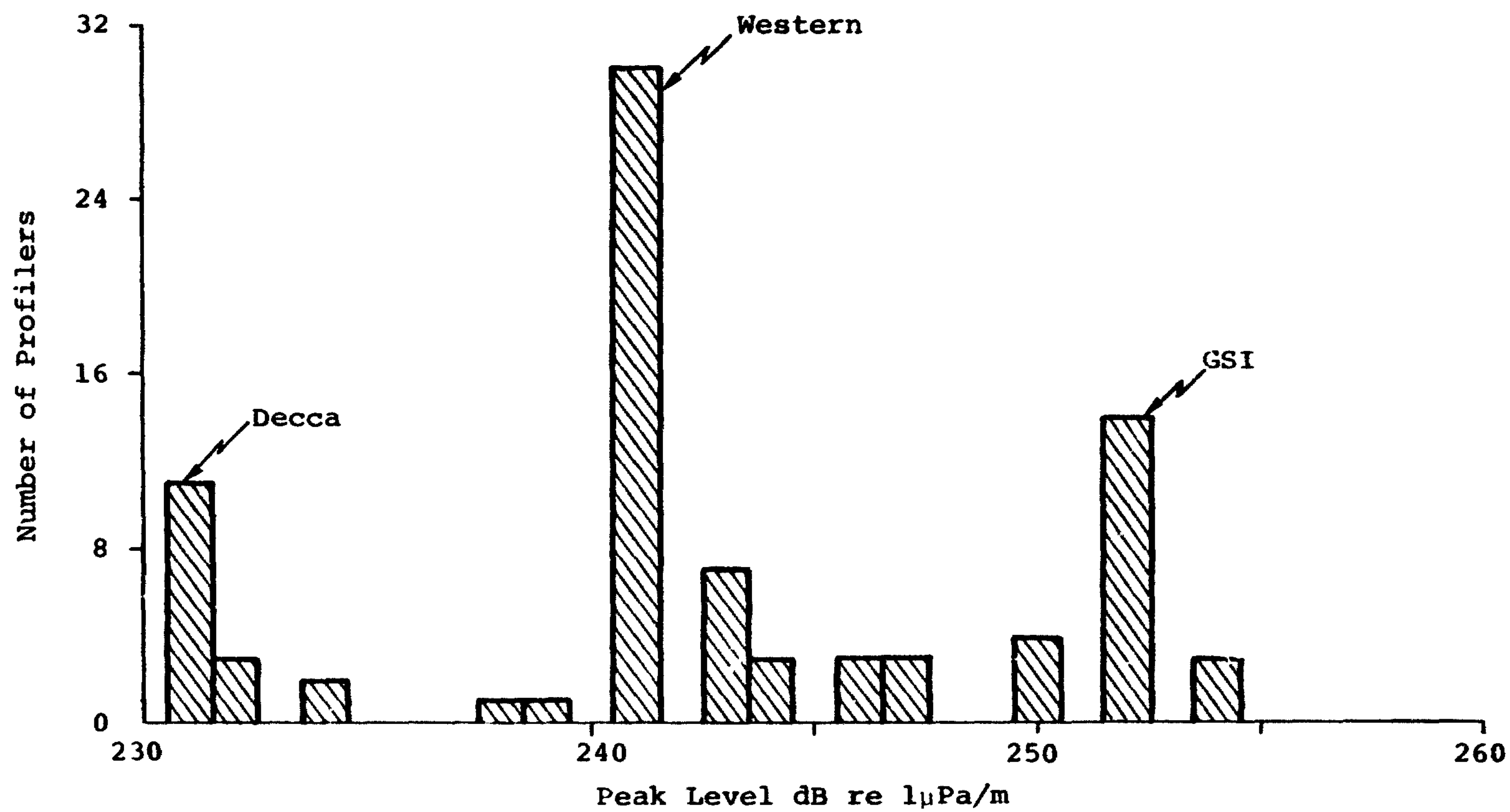
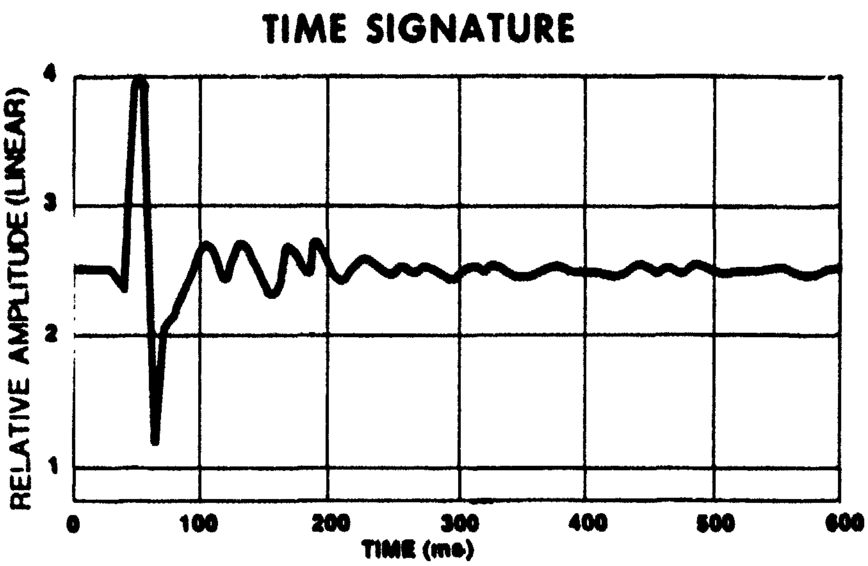


Figure 3-38. (U) Distribution of Seismic Profiler Source Levels. (U)



Peak Level 252 dB//µPa

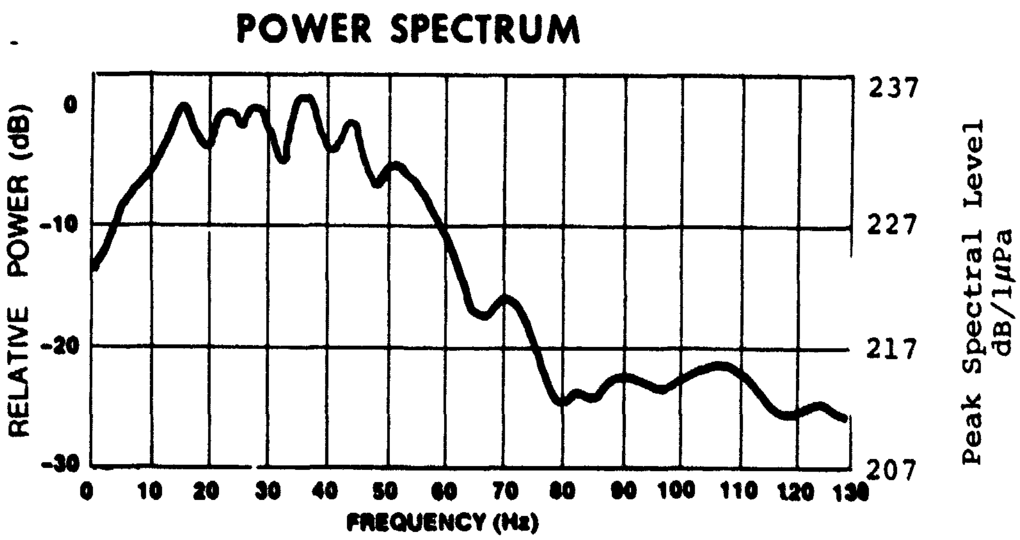


Figure 3-39. (U) Bolt Air-Gun Array: Pressure Signature and Relative Power Spectrum (near field measurements made by Digicon, Inc.).

Gun Pressures: 2000 psig   Gun Depths: 9 m (30 ft)
No. of Guns in Array: 24

Composition of Array: eleven 0.16-liter (10-in^3) guns; six 0.33-liter (20-in^3) guns; three 0.5-liter (30-in^3) guns; two 0.7-liter (40-in^3) guns; one 1.3-liter (80-in^3) gun; one 2.0-liter (120-in^3) gun

(After Reference 41).

(C) During the APEX experiment off Nova Scotia, a profiler of the same design passed within a few miles of a set of bottom hydrophones. The signals were processed for rms source spectral level over a period of 7 min. The repetition rate of the air gun was 10 sec. Figure 3-40 shows the resultant computed source level using measured propagation loss. The source level in the 10 to 40 Hz region is 191 dB//μPa at 1 m. Since this level is considerably lower than the previously used reference, we will attempt to relate the two:

191 dB - RMS source spectral level
23 dB - Profiler duty cycle 50 ms/10 sec
17 dB - 10 log (60 - 10) Hz
12 dB - Directivity
243 dB - Leaving 9 dB of the peak level unexplained.

Unaccounted for factors that could easily make up the 9 dB difference are crest factor, energy below 10 Hz, assumed directivity and processing.

(U) Thus it appears that the 252 dB peak downward source level and a 240 dB horizontal source level can be used with some confidence for the Geophysical Services Inc. profilers. At the same time, the directionality of the air gun array was measured at two azimuths, separated by 52 degrees. The measurements were made in approximately 200 ft of water. Figure 3-41 shows the results. There appears to be no significant azimuthal variation of source level at the two azimuths.

(U) During the APEX exercise, SEDCO J was being monitored by an over-the-side bottomed hydrophone in 192 ft of water. Figure 3-42 shows the received pressure-time curve for two consecutive air gun impulses. The profiler at this time is estimated to be about 20 miles away. The pressure levels at about 6 seconds are representative of the rig itself. (The received spectra of the rig were shown in Figure 3-30). In Figure 3-42 note the nearly single frequency ground wave that precedes the

(C)

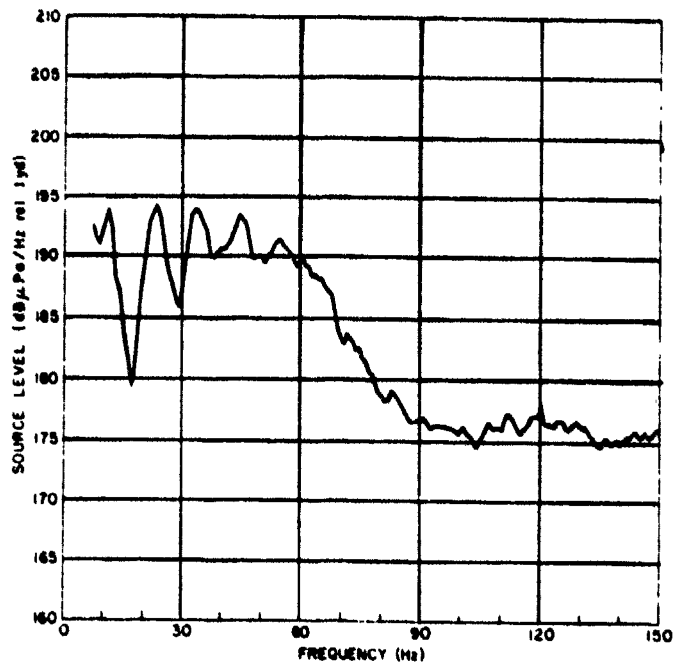


Figure 3-40. (C) Estimated Seismic Profiler Source Spectrum (U).

(C)

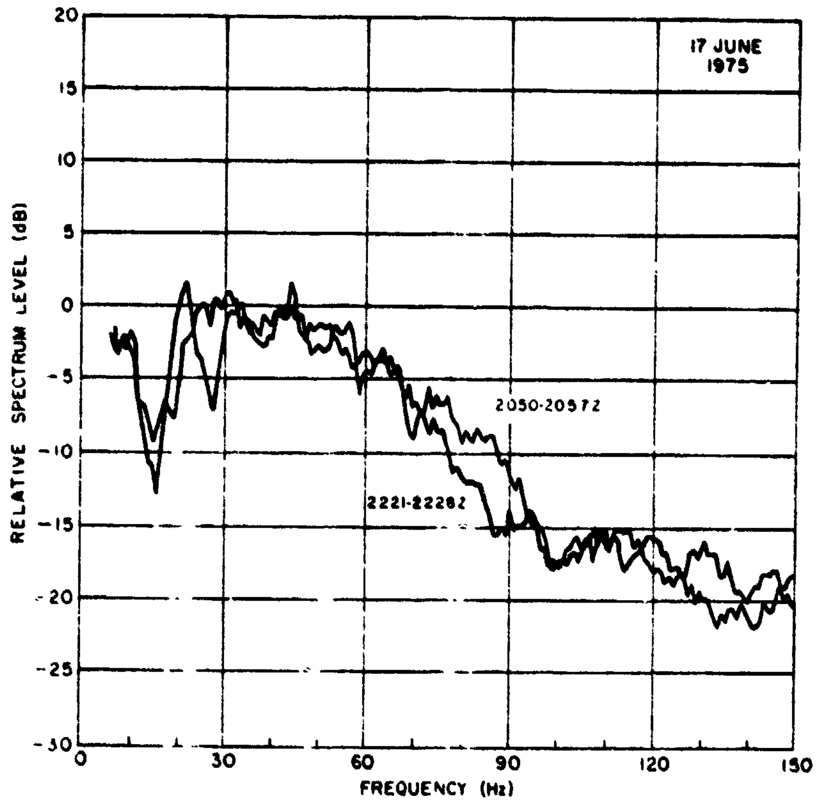


Figure 3-41. (C)Spectra of energy received on Site 2, hydrophone 7 from seismic profiler at different aspects (levels adjusted for comparison of spectrum shape) (U).

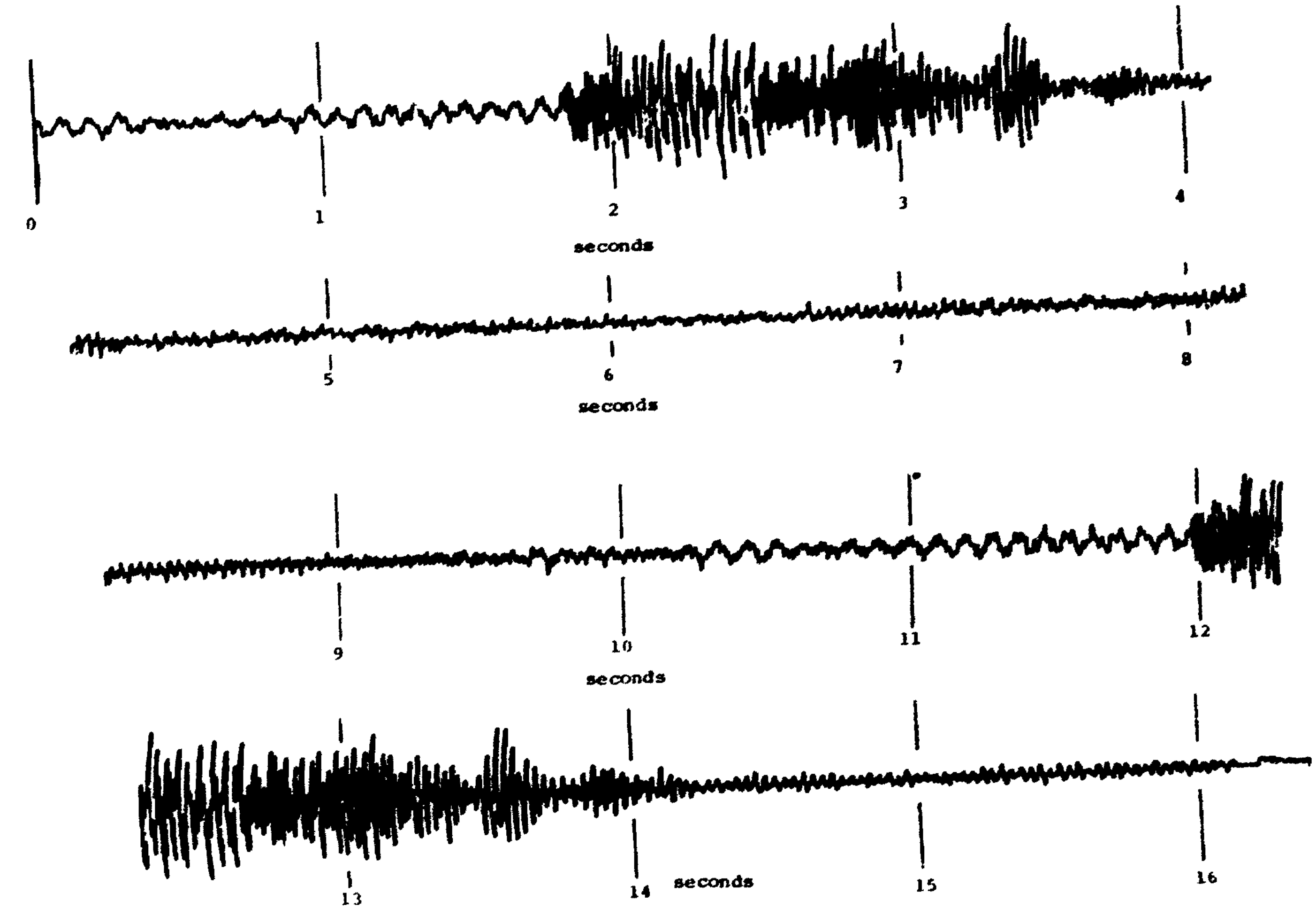


Figure 3-42. (U) Pressure (Voltage) Trace of Bottom Hydrophone Output During Reception of Air-Gun Pulses. SEDCO J, 16 June 1975, Beginning at Approximately 2017:19 ADT. (From Reference 38).

(U)

broadband water wave arrival in the 10 to 12 sec time frame. Figure 3-43 is the spectrum of a single received air gun pulse superimposed on the rig noise. The high level component at about 11 Hz indicates the relative amount of spectral energy in the ground wave.

(U) From this data one concludes that the peak profiler signal will be approximately equal to the anticipated broadband ambient noise level (102 dB//μPa) at a receiving hydrophone in the Gulf of Mexico with the propagation loss to the profiler of approximately 135 dB. Interference from the profilers, therefore, appears to be likely and the Exercise should consider their operation. In addition, the electronics overload characteristics need to be considered for peak level clipping if data are to be gathered during times when the profilers are operating.

(U) Sleeve Exploders (U)

(U) The sleeve exploder derives its impulsive signal from igniting a mixture of gas, oxygen and air in a rubber-covered cylinder. The bubble pulse present in the air gun and sparker source is not present in the sleeve because of the rubber-covered cylinder. Figure 3-44 shows the pressure-time trace of a single Type A sleeve exploder. The Type A sleeve does not use any air. The peak pressure level attained is 217 dB//μPa for a single sleeve. The relative spectral levels are converted to peak spectral levels by the same method used for Figure 3-39 with respect to air guns. An array of six Type C sleeves was used to obtain the 242 dB//μPa level shown in Figure 3-38. No other information on sleeve exploders was located.

(C) Sparkers (U)

(C) The sparker derives its impulsive signal from dumping 4.2 to 8.4 kilojoules of electrical energy across two electrodes in the water. The electrical spark energy vaporizes the water, causing a shock wave and

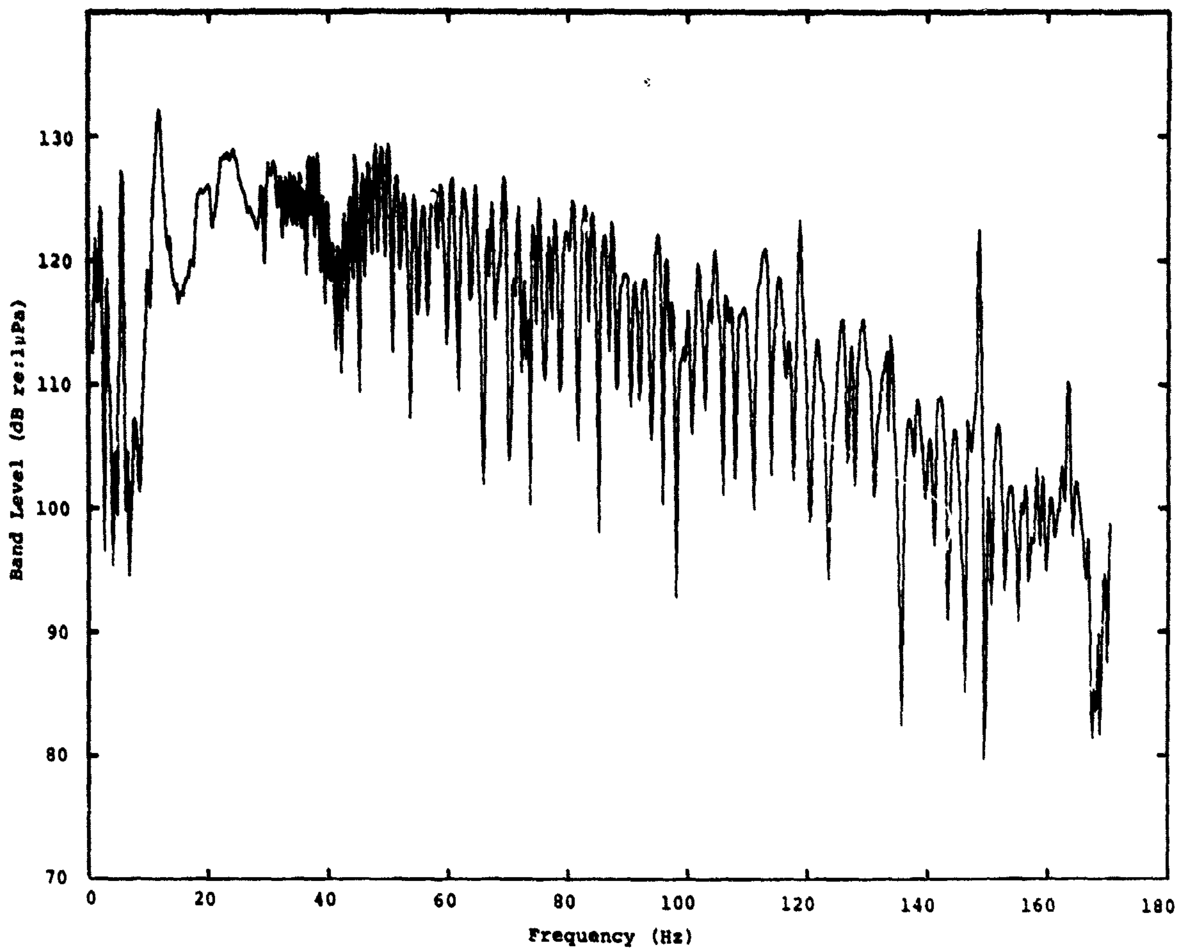


Figure 3-43.(U) Frequency Spectrum of Acoustic Energy Received on Bottom Hydrophone During 4.1 sec Period. This Pulse Corresponds to the First Pulse of Figure 3-42 (U)

(From Reference 38).

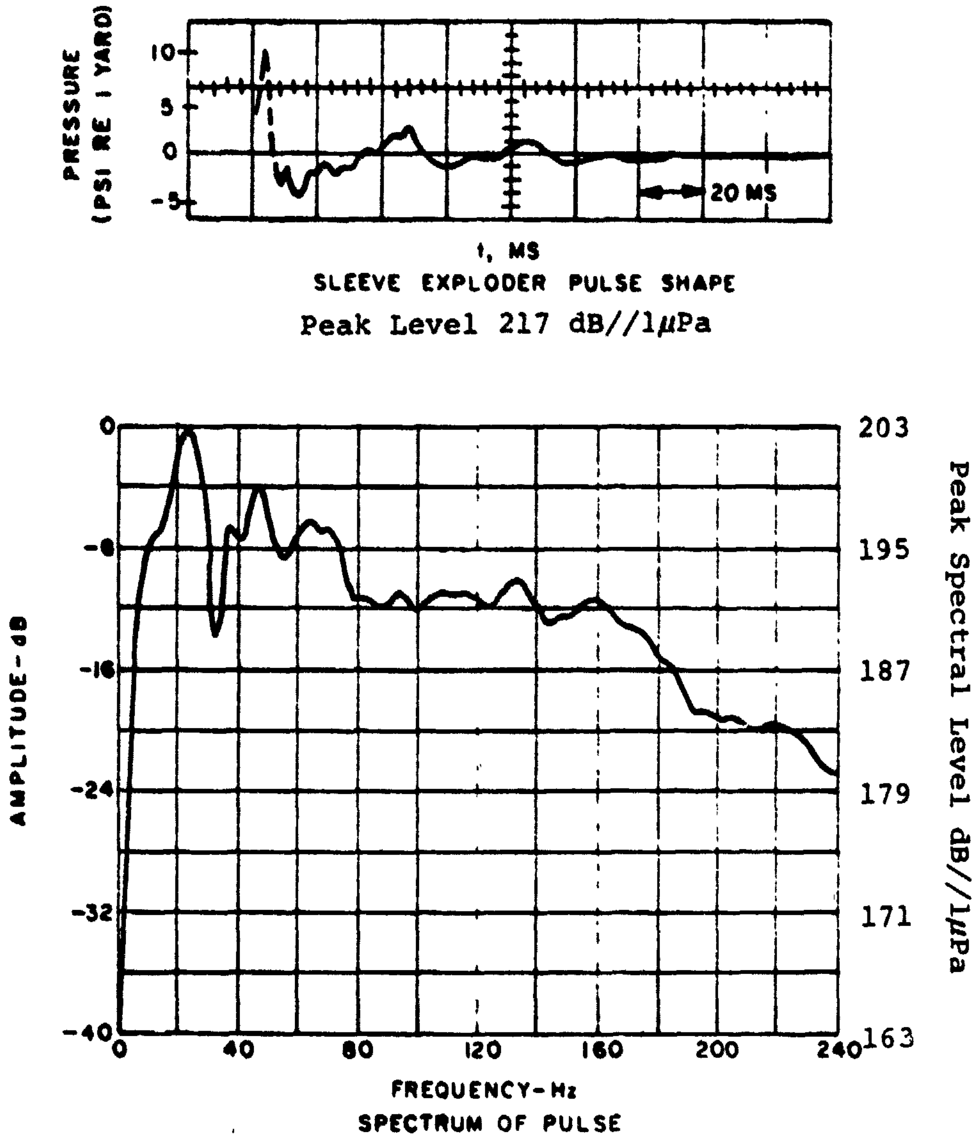


Figure 3-44. (U) Sleeve Exploder Pulse Shape and Relative Power Spectrum. (U)

(After Reference 41).

(C)

a series of oscillating bubble pulses. Sparkers are generally used singly for high resolution, shallow bottom surveys. As used, the spectrum is centered at about 150 Hz and covers a band of 80 to 200 Hz (Reference 41).

(U) During the CHURCH STROKE III Exercise, heavy profiler activity can be expected in the T-LA region of the Gulf of Mexico. We can expect a lot of the activity to be on the shelf where geologic structures are being re-explored and refined. However, we can also expect activity on the deeper slope. It appears that PEMEX is going to concentrate on their Bay of Campeche find. Therefore, we can expect most of the activity to be on the western side of the Yucatan Atoll with the possibility of exploring the structure around the atoll to Belize. Activity in Belize, Honduras and Nicaragua has been at a minimal level for some time. If activity does develop it will probably not be widespread.

3.3.5 (U) Adequacy of Data (U)

(U) Information on the location of mobile oil rigs and production platforms in the T-LA area is excellent. Location information for the Mexican platforms and rigs is now inferred from periodical articles and no method of obtaining more definitive information has been established. The location of any rigs working off Belize, Honduras and Nicaragua is unknown.

(U) The source levels of the semisubmersible type, similar to SEDCO J, can be inferred from that data. There are essentially no source level data on the other types of rigs and the production platforms, except that they are similar to a medium-sized merchant ship.

(U) The source levels of the seismic profilers are known well enough for planning purposes. The procedure for obtaining the locations of the profilers during the exercise is being formulated.

3.4 (U) Shipping Distribution (U)

L. Solomon
Planning Systems Inc.

(U) Historical Temporal Shipping (HITS) is the documented data base which has been queried for historical shipping densities in the Gulf of Mexico and the Caribbean Sea.[42] This data base has been developed over a period of years, drawing upon a wide variety of sources, worldwide.

3.4.1 (U) Shipping Distribution Source (U)

(U) HITS is primarily based upon the worldwide shipping traffic for 1972 and updated to 1978. The routes by which the ships proceed from port to port were developed and presented in the Ocean Route Envelopes (ORE) report.[43] The data base presents shipping densities in 1° squares by month, season and annual averages for five different types of vessels: merchants, tankers, supertankers, fishing vessels, and oil rigs; there are 12×10^{6} entries which are available for analysis.

(U) The data available to HITS and ORE was the traffic of 2425 ports. The number of possible routes between all of these ports is 2,941,525. This was too large to work with and therefore, the concept of canonical ports was developed. Many of the world's ports are relatively close to a major port. Furthermore, the routes from such secondary ports near the major ports to secondary ports near another major port are very similar to the route between the two major ports. A careful analysis of world ports resulted in the designation of 50 major ports as canonical ports. In the Gulf of Mexico, New Orleans is the only canonical port. Other ports such as Houston, Galveston, Corpus Christi, Brownsville, Tampa, and Tampico are all secondary ports.

(U) HITS was designed to concentrate on open ocean distributions, and that is where it has been validated. The problem of shipping distributions in small bodies of water like the Gulf of Mexico is more complex than the open ocean and the accuracy of the estimate suffers accordingly.

3.4.2 (U) Representative Shipping Fields (U)

(U) Figures 3-45, 3-46, 3-47, 3-48 and 3-49 are representative data for large tankers summer average, tankers summer average, merchants summer average, fishing vessels summer average, and oil rigs. The first 2 figures show no tanker traffic in the Western Gulf. This is an artifact of the distribution caused by the canonical port concept. Recent developments in tanker traffic have also caused a necessary change to this distribution. Figure 3-47 is an indication of merchant traffic which is probably low in the Western Gulf and high in the Eastern Gulf. This is also due to the use of canonical ports. The fishing vessel population as represented in Figure 3-48 is HITS estimate of where the fishing fleets are, based on secondary sources, noted and discussed in HITS. The uniformity of the distribution is suspect and will be modified as required. The oil rig distribution refers only to the mobile rigs. Figure 3-49 represents old data and must be updated. At the present time, there are 92 movable rigs in the Gulf. However, these rigs may move very frequently and generally any distribution will be out of date within 30-90 days of its issue.

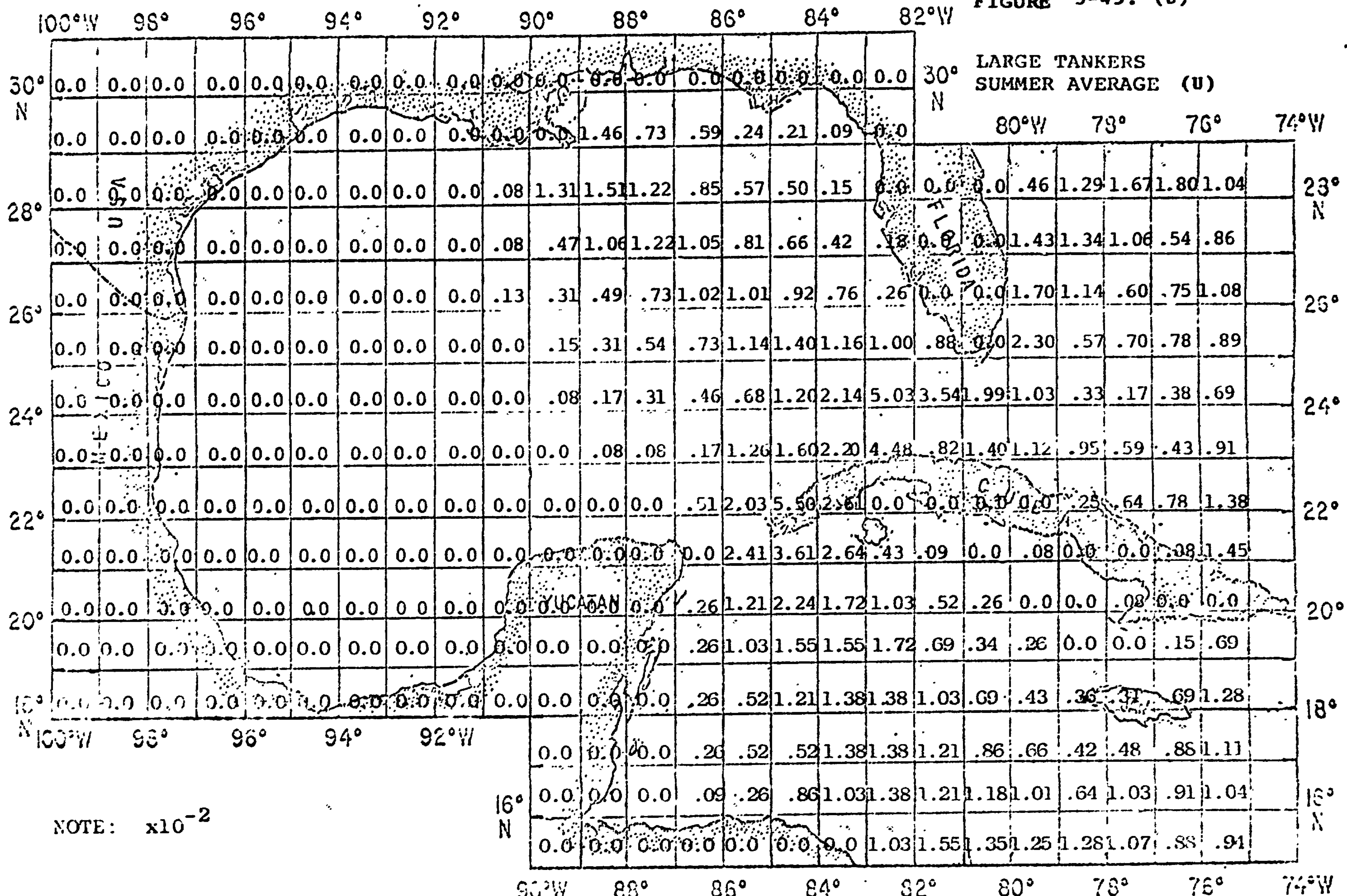
(U) The shipping density shown in Figure 3-50 combines the data for merchant vessels, tankers and large tankers shown in Figures 3-45 through 3-47, with adjustments made to provide more realistic densities in the Western Gulf. The data in Figure 3-50 have been furnished to NORDA for use in model runs.

3.4.3 (U) Adequacy of the Shipping Density Data (U)

(U) From the validation of the HITS data base as reported in the documentation, there is a good basis for believing in the general validity of the techniques employed to develop the data base and the resulting data in the base itself. The data base in the Gulf of Mexico and the Caribbean Sea needs modification due to the artifacts in the data base generation algorithms. However, for preliminary calculations the data base may be reasonable.

FIGURE 3-45. (U)

LARGE TANKERS
SUMMER AVERAGE (U)



NOTE: $x10^{-2}$

FIGURE 3-46. (U)

TANKERS SUMMER AVERAGE (U)

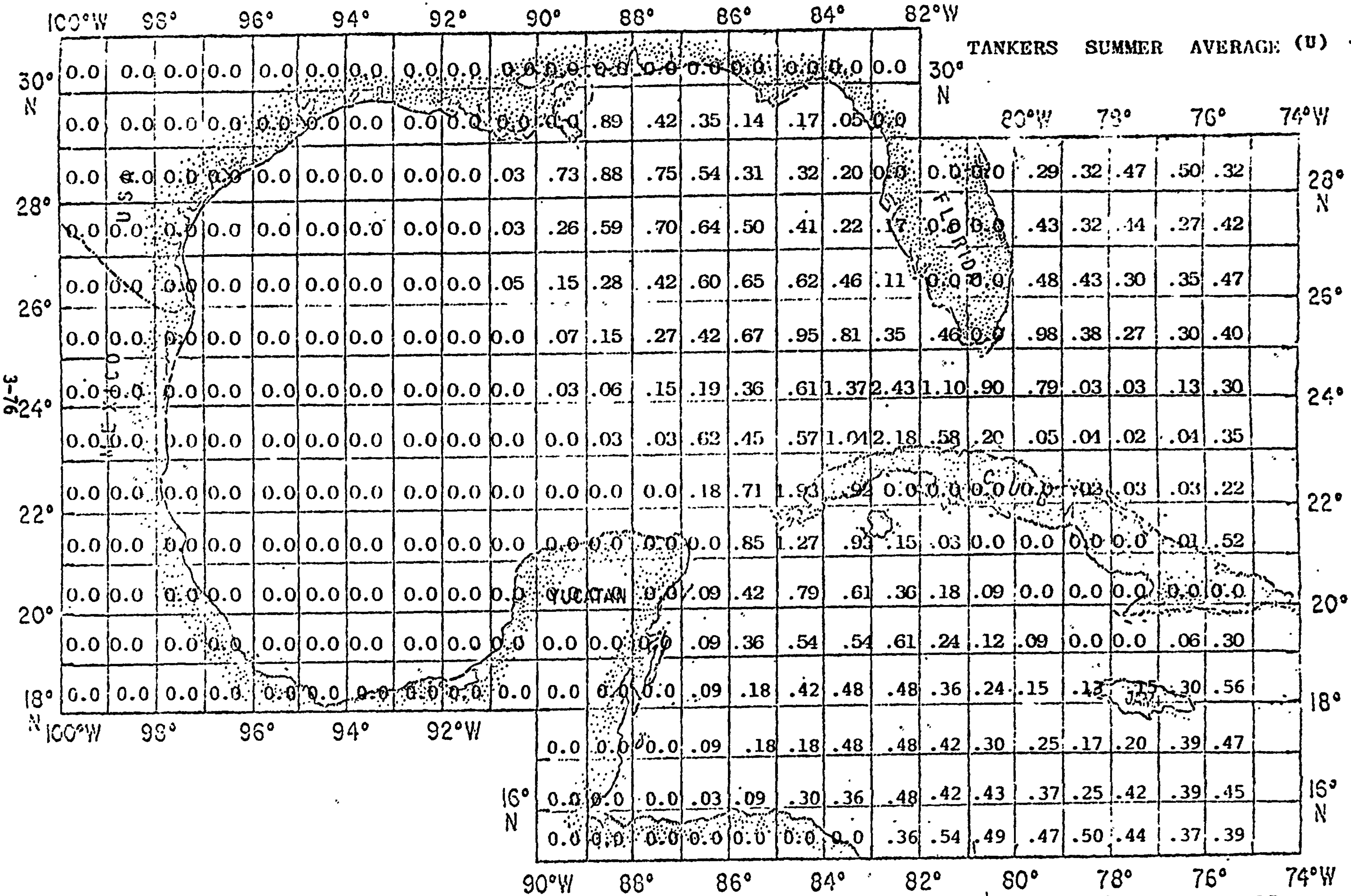


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FIGURE 3-47. (U)

MERCHANTS SUMMER AVERAGE(U)

100°W		98°		96°		94°		92°		90°W		88°		86°		84°		82°W		80°W		78°		76°	
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0								
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.68	2.66	2.30	1.38	1.27	.81	0.0								
0.0	0.0	0.0	0.0	.76	.74	.76	.76	.82	1.08	4.22	4.72	3.99	2.95	2.04	1.88	1.10	0.0	0.0	0.0	1.35	1.57	2.03	1.93	1.21	
0.0	0.0	.60	.60	.60	.64	.64	.64	.74	1.02	2.03	3.44	3.78	3.32	2.56	2.16	1.29	1.06	0.0	0.0	2.09	1.60	1.64	1.01	1.65	
0.0	0.0	.53	.56	.50	.58	.58	.58	.60	.98	1.45	1.94	2.37	3.01	2.92	2.70	2.37	1.01	0.0	0.0	2.44	2.16	1.24	1.58	2.12	
0.0	0.0	0.0	.50	.44	.37	.35	.35	.47	.55	.89	1.25	1.65	2.10	3.07	3.95	3.44	2.11	2.05	0.0	4.27	1.80	1.47	1.46	1.54	
0.0	0.0	.50	.42	.32	.27	.28	.28	.29	.32	.50	.69	.97	1.27	1.69	2.94	5.84	10.8	4.77	3.71	3.05	.31	.10	.48	1.10	
0.0	0.0	.50	.42	.32	.22	0.0	0.0	0.0	0.0	0.0	.18	.18	.37	2.29	3.03	5.92	12.0	2.86	1.46	.81	.77	.24	.18	1.27	
0.0	0.0	.50	.42	.32	.22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.87	3.48	9.0[illegible]	5.01	0.0	0.0	0.0	0.0	.65	.21	.20	.90	
0.0	0.0	.30	.42	.32	.22	.12	.12	.22	.12	.12	0.0	0.0	0.0	1.13	6.40	5.01	1.27	.68	.53	.51	0.0	0.0	.07	1.98	
0.0	0.0	0.0	.42	.28	.25	.25	.25	.25	.20	0.0	0.0	0.0	.56	2.19	3.96	3.27	2.09	1.20	.76	0.0	0.0	.01	0.0	0.0	
0.0	0.0	0.0	.42	.32	.28	.28	.28	.25	0.0	0.0	0.0	.22	.65	1.89	2.66	2.78	3.07	1.30	.59	.44	0.0	0.0	.23	1.10	
0.0	0.0	0.0	0.0	.32	32	.32	0.0	0.0	0.0	0.0	0.0	0.0	.61	1.00	2.07	2.36	2.36	1.77	1.18	.74	.60	.53	1.10	2.04	
										0.0	0.0	.22	.61	1.02	.88	2.36	2.36	2.07	1.48	1.12	.69	.77	1.41	1.92	
										0.0	0.0	.23	.36	.65	1.68	1.97	2.56	2.07	2.00	1.71	1.06	1.69	1.61	1.74	
										0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.98	2.78	2.30	2.10	2.12	1.89	1.63	1.81	

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FIGURE 3-48. (U)

FISHING VESSELS SUMMER (U)

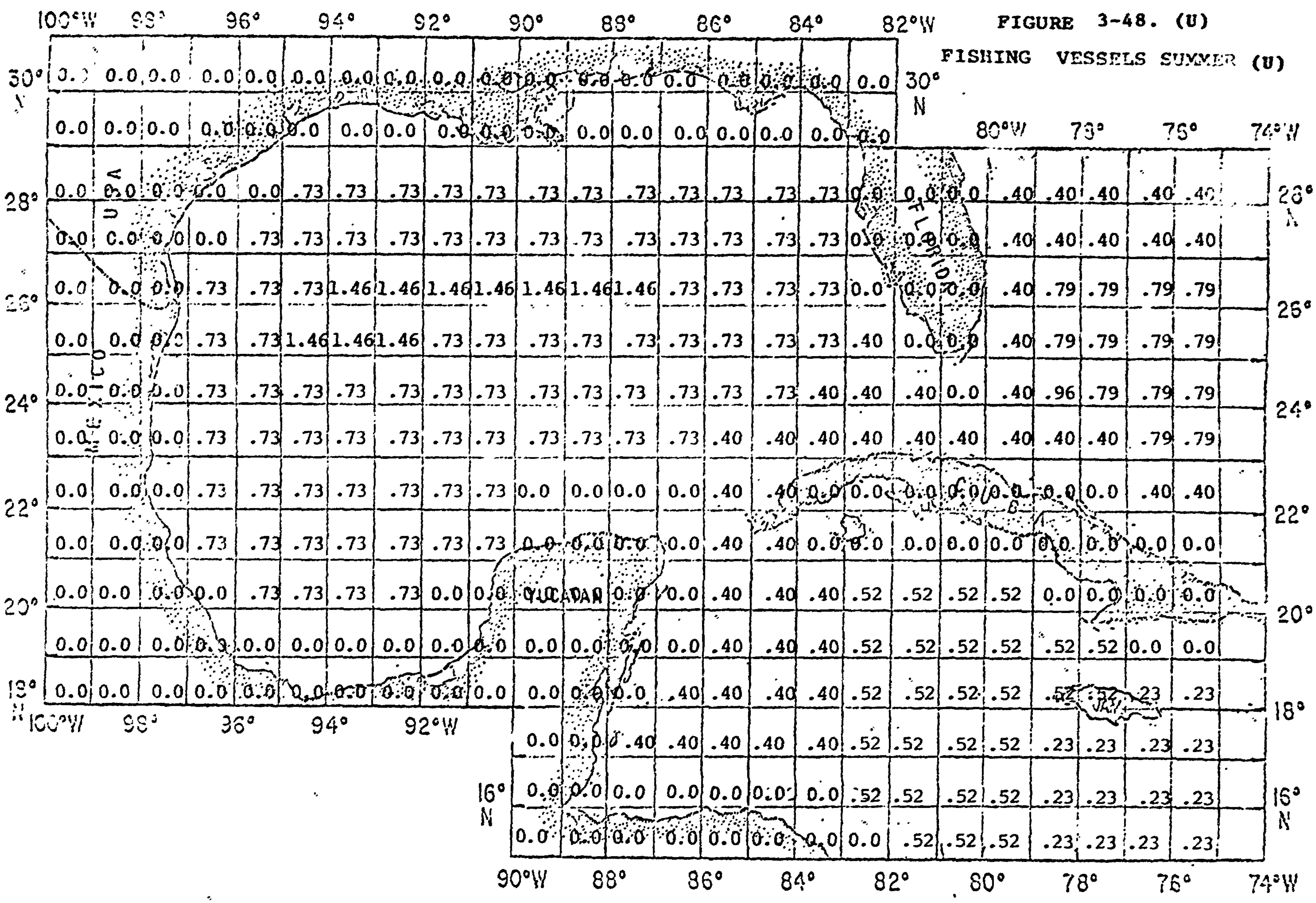

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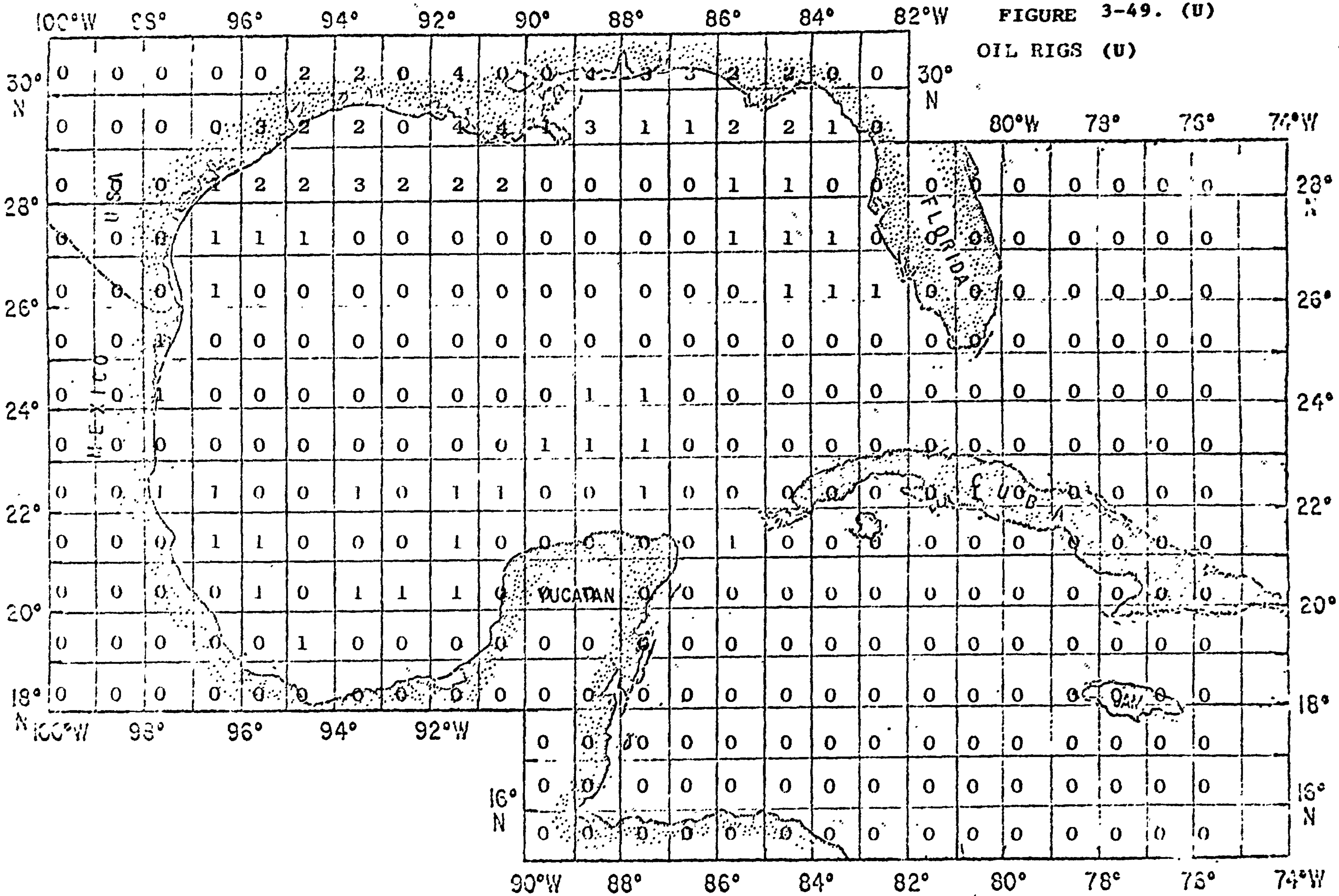
FIGURE 3-49. (U)

OIL RIGS (U)



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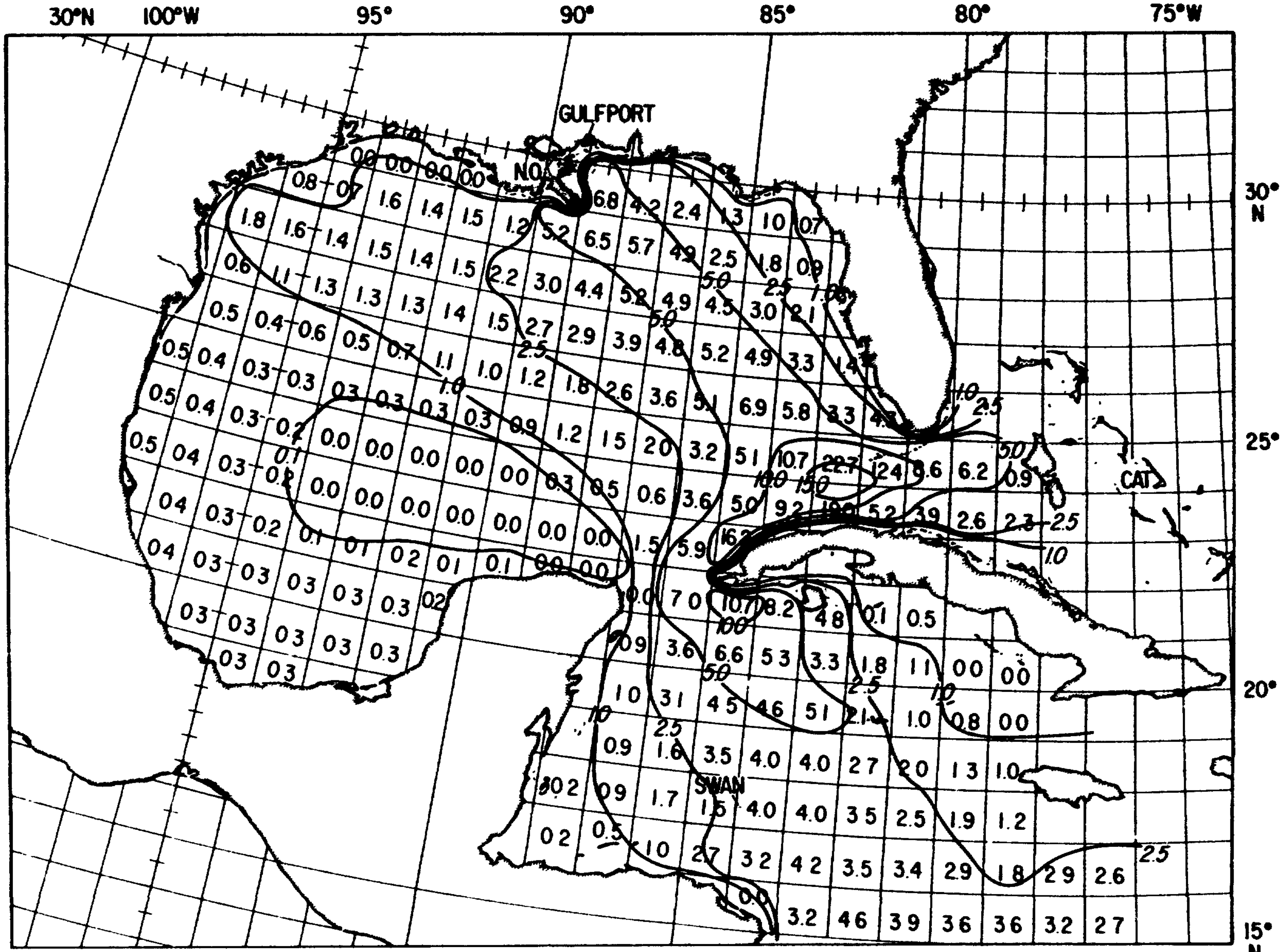

FIGURE 3-50. (U) SHIPPING DENSITY BASED ON HITS FOR JULY 78
SUM OF MERCHANTS, TANKERS & LARGE TANKERS (U)

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4.0 (U) MODELING SUMMARY (U)

J. Davis
NORDA-320

4.1 (U) Propagation Loss (U)

4.1.1 (U) Propagation Loss Models (U).

(U) The Gulf of Mexico-Caribbean Sea areas present a severe modeling challenge. If the bottom has reasonable reflectivity, a 3-dimensional (3-D) transmission loss model will be required to properly model the area. This model must be capable of treating reverberant effects in the Cayman Trough and Catoche Tongue, cross slope effects (redistribution of energy in the vertical and horizontal) and possible backscatter going up a steep slope with a good bottom. Two candidate 3-D models that may be able to handle these effects are the 3-D PE currently under development at NRL[1] and the horizontal ray theory model at NUSC[2] . It is unlikely that the NRL model can be implemented in time to impact the CHURCH STROKE III preassessment and the NUSC model would likely take over 6 months to implement. In either case a 3-D model will be critically input limited. It may also be necessary to be able to model transmission through subbottoms over irregular bathymetry. There are no models to our knowledge capable of dealing with this situation. Since the areas are mostly bottom or nearbottom limited, knowledge of bottom properties is extremely important in order to assess the impact of these effects. The paucity of directly measured acoustical bottom properties precludes such an assessment.

(U) From a practical point of view we are restricted to 2-D models - models that assume cylindrical symmetry. For this reason it is extremely important that the experiments address some of the possible 3-D effects in order to provide a good data set against which to assess the 2-D model performance limitations in the area and to serve for evaluation of forthcoming 3-D models.

(U) Candidate 2-D models are PE[3] (with a critical angle treatment of the bottom), UNIMOD[4] (an SAI combination of PE for waterborne energy and either MPP[5] or FACT[6,7] for bottom-interacting energy) and various ray trace programs: MPP, RAYWAVE[8], TRIMAIN[9], and GRASS[10,11]. A crude but less expensive model is ASTRAL[12,13]. PE has a demonstrated ability to reproduce some range-dependent environmental effects on the transmission loss and in particular can model slope conversion - a process of critical importance for prediction in regions with reflective slopes. It does have the drawbacks that its bottom model is approximate and that it must be used with caution over a steep slope having a good bottom where steep angle energy may be important. UNIMOD appears to be promising but is largely untested. The other ray trace programs can provide vertical arrival information and may be capable of modeling slope conversion. ASTRAL is extremely promising, pending further testing, from an economic point of view. While it provides average results, it has been evaluated against PE for an absorbing bottom[12,13] and apparently can model slope conversion for a reflective bottom (see Section 4.1.2).

(U) Of the 1-D models that may be useful in predicting medium range propagation in large homogeneous basins where the bottom is good, or short range in choke points or straits where the bottom may be poor, a model such as FACT may provide reliable transmission loss estimates and vertical arrival structure information when supplemented by a normal mode program, such as the one at ARL/UT[14], that treats subbottom structure and absorption.

(U) For propagation loss along selected look directions, we recommend use of PE, UNIMOD (if it can be implemented in time), ASTRAL, FACT and the ARL normal mode program. Propagation loss as input to ambient noise estimates suffers from environmental data base and automation difficulties that are discussed in Section 4.2.1.

4.1.2 (U) Propagation Loss Model Runs (U)

(U) A limited number of transmission loss model runs are available for the Gulf of Mexico-Caribbean area. These runs are based on a

(U)

combination of AUTO-OCEAN[15] (5° resolution) and RSVP[16] detailed retrieval profiles and SYNBAPS[17, 18, 19] bathymetry. Figure 4-1 indicates the radials from particular sites for which the environment has been processed while Table 4-1 lists the transmission loss calculations actually performed.

(U) The FNWC descriptions for the area are a uniform Type 4. The bottom treatment in PE is such that all energy is returned to the water column for grazing angles from 0° to the critical angle and completely absorbed for grazing angles greater than the critical angle. It is not clear what critical angle one should associate with a Type 4 bottom for PE input, since a Type 4 has 2 dB constant loss from 0° grazing up to 11°. PE calculations at 50 Hz were made along BN7 with SYNBAPS bathymetry, RSVP profiles (see Figure 4-2), and critical angles of 5°, 8° and 11°. A FACT run was also made with range independent environment with a Type 4 bottom. Figure 4-3 is a plot of these results for a 100 m receiver depth and a 100 m source depth. This figure illustrates not only the sensitivity of the transmission loss to the assumed bottom type for this bottom-limited area but also serves to underline the fact that there is no unique critical angle for a Type 4 bottom. An 11° angle is obviously too high, and 8° is too low at short ranges and too high at the longer ranges, and a 5° angle is too low.

(U) Figures 4-4, 4-5 and 4-6 show the PE transmission loss (5 nm intensity average) along BN5, BN7 and BN2 (Cayman Trench) for a receiver depth of 100 m and source depths of 20, 100 and 200 m assuming a critical angle of 11° throughout. We have not yet determined whether an 11° critical angle is a reasonable representation of the bottom along these paths. By calculating the arc cosine of the ratio of the sound speed at the receiver depth to the sound speed at the bottom of the water column,

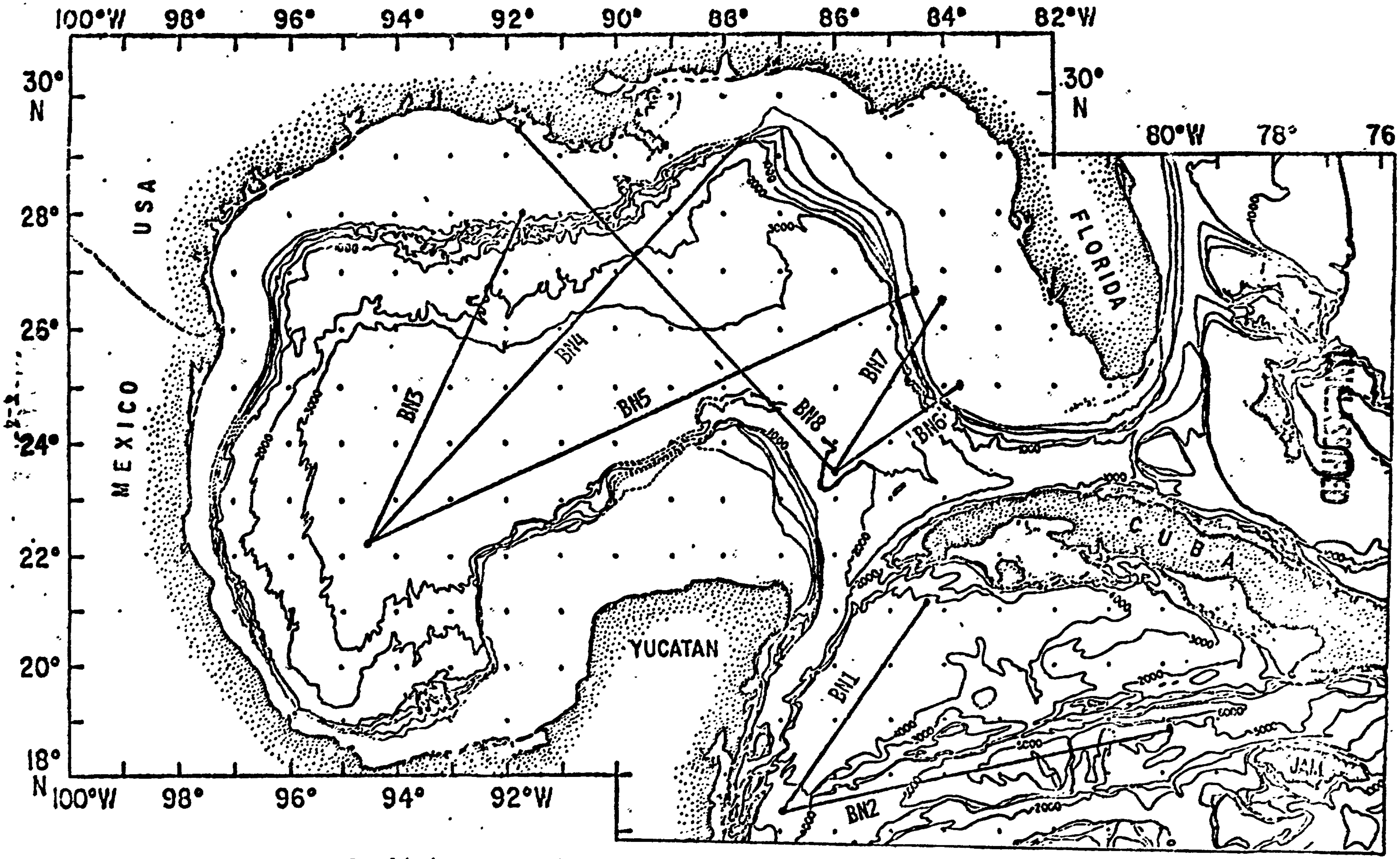

Figure 4-1. (U) Preliminary Tracks for Propagation Loss Model Runs. (U)

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Table 4-1. (U) MODEL RUN CATALOG (U)

Track	Model	Receiver Depth (m)	Source Depth (m)	Critical Angle Bottom Class	Comments
BN3	PE	100	20,100, 200,300	1^0	totally absorbing bottom
BN3	PE	"	"	5^0	basin, slope, shelf critical angles
BN3	PE	"	"	11^0	
BN3	PE	"	"	$5^0,19^0,11^0$	basin, slope, shelf critical angles
BN3	PE	300	"	11^0	
BN3	PE	100	"	$5^0,19^0,11^0$	increased SVP interpolations
BN3	PE	300	"	"	
BN3	PE	860	"	"	axial depth
BN3	PE	300	20,100,200, 300,800,1000	$11^0,19^0,19^0$	single SVP
BN3	PE	"	"	$11^0,23^0,23^0$	single SVP
BN3	PE	"	"	$11^0,19^0,19^0$	155 nm slope = $.7^0$
BN3	PE	"	"	"	110 nm slope = $.9^0$
BN3	PE	"	"	"	55 nm slope = 2^0
BN3	PE	800	20,100,200 300,800,1000	"	155 nm slope = $.7^0$
BN3	PE	"	"	"	110 nm slope = $.9^0$
BN3	PE	"	"	"	55 nm slope = 2^0
BN3	PE	20,100,200 300,800,1000	100	$11^0,19^0,5^0$	shelf, slope, basin reverse track
BN3	PE	800	20,100,200 300,800,1000	$5^0,11^0,11^0$	extended track to 427 nm
BN3	PE	800	"	$5^0,19^0,19^0$	extended track to 427 nm
BN3	ASTRAL	100	20,100,200	"	AUTO-OCEAN data, bottom classes
BN3	ASTRAL	"	"	3,1,4	reversed track to match PE run
BN3	ASTRAL	800	"	4,1,3	extended track (all of following)
BN3	ASTRAL	"	300,800,1000	"	
BN3	ASTRAL	300	20,100,200	"	
BN3	ASTRAL	"	300,800,1000	"	
BN3	ASTRAL	100	20,100,200	"	
BN3	ASTRAL	"	300,800,1000	"	
BN3	ASTRAL	800	20,100,200	"	bathymetry at 50 nm intervals
BN3	ASTRAL	"	"	"	AUTO-OCEAN bathymetry
BN3	ASTRAL	"	"	4,1,1	BC=1 on shelf
BN3	ASTRAL	"	"	4,1,3	single step bathymetry for slope
BN7	PE	100	"	0^0	totally absorbing bottom
BN7	PE	"	"	5^0	
BN7	PE	"	"	8^0	
BN7	PE	"	"	11^0	
BN7	PE	300	20,100,200 300,800,1000	19^0	
BN7	PE	"	"	$11^0,23^0$	
BN7	PE	800	"	19^0	
BN7	PE	"	"	$11^0,23^0$	
BN7	PE	100	"	19^0	
BN7	PE	100	"	$11^0,23^0$	
BN7	ASTRAL	100	20,100,200	"	AUTO-OCEAN data, bottom classes

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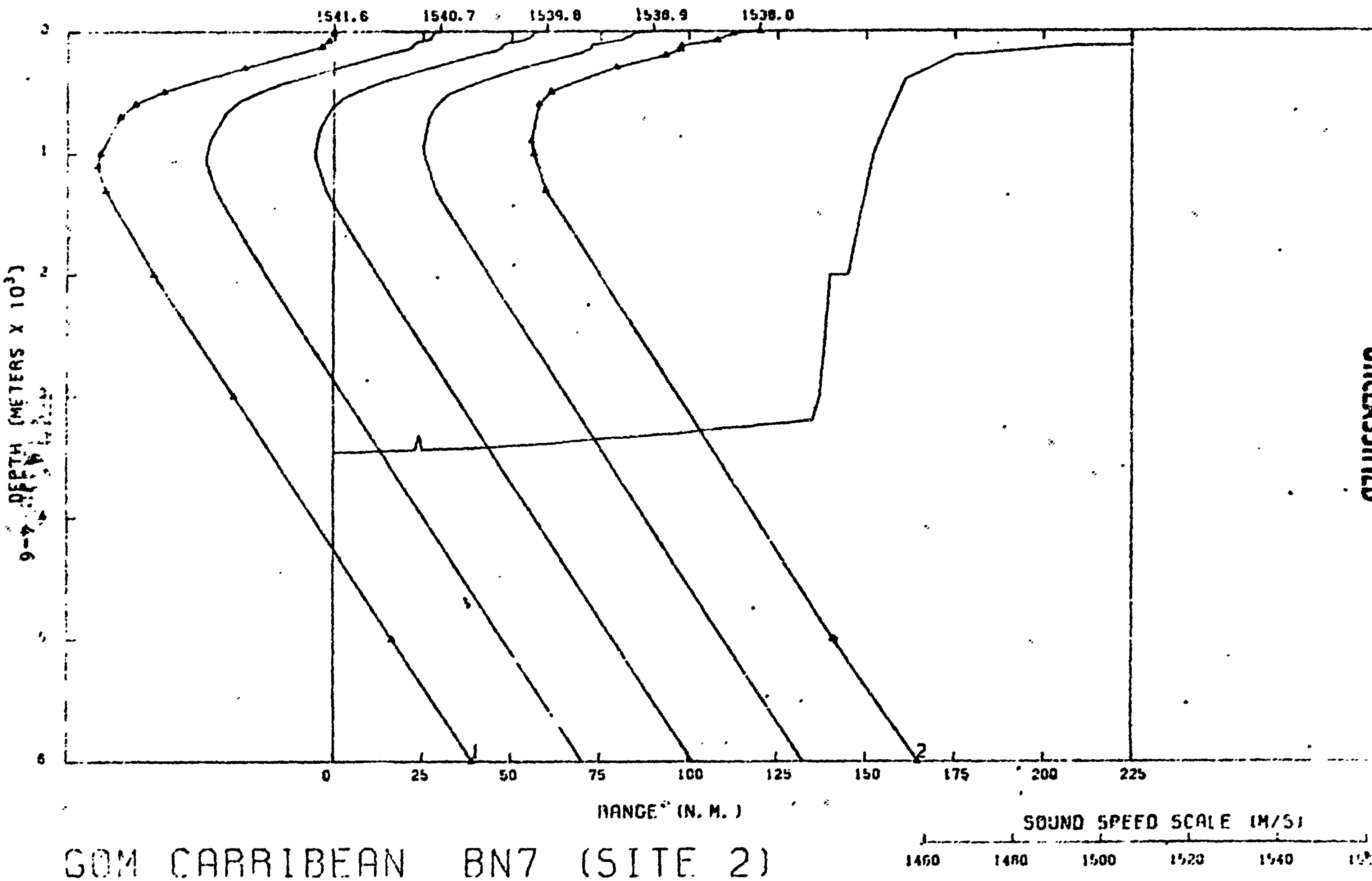

Figure 4-2. (U). Sound Velocity and Bathymetry Profiles for Track BN 7. (U)

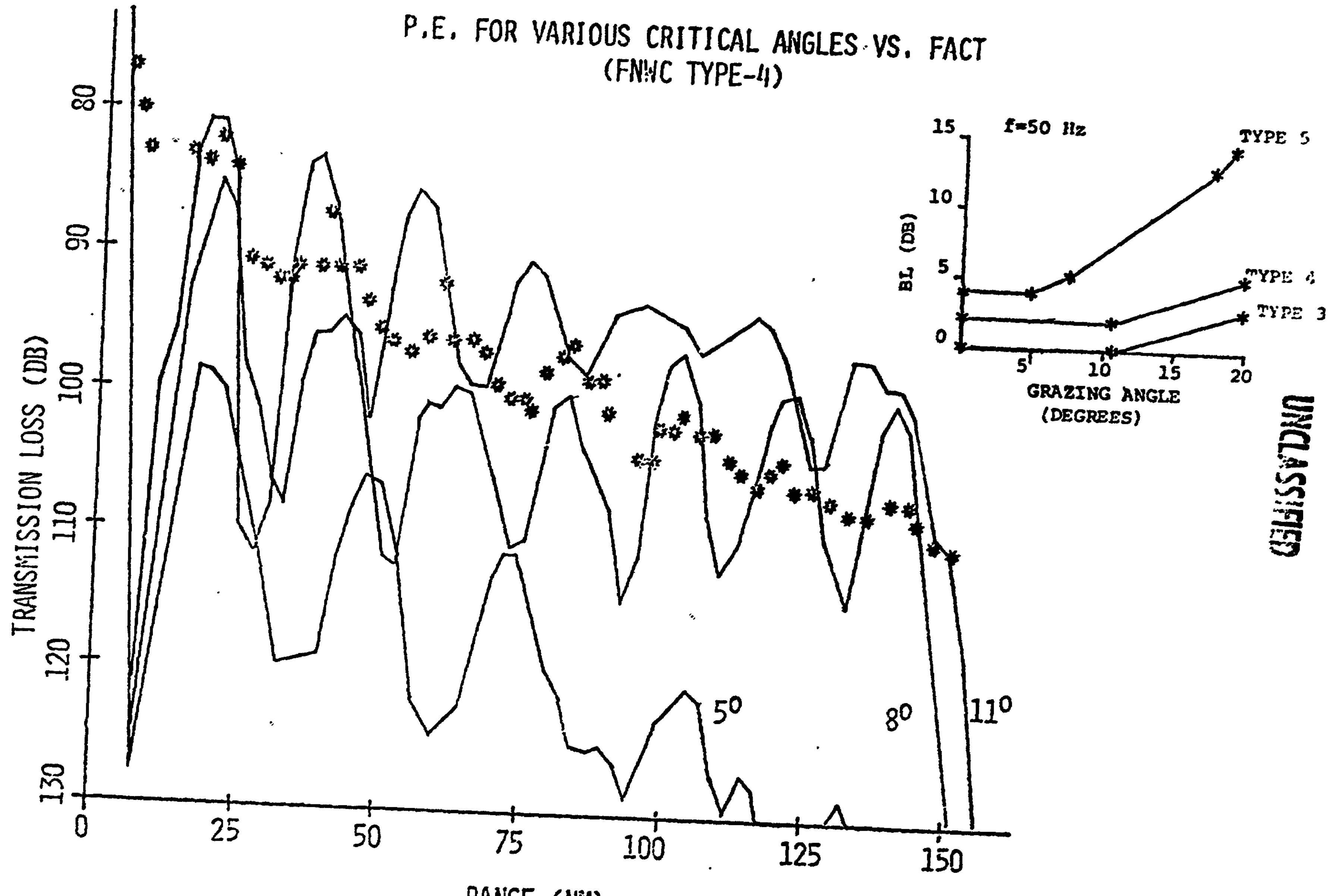

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Figure 4-3. (U) PE Propagation Loss for Various Critical Angles vs FACT Propagation Loss Along Track BN 7. Source Depth 100 m, Receiver Depth 100 m. (U)

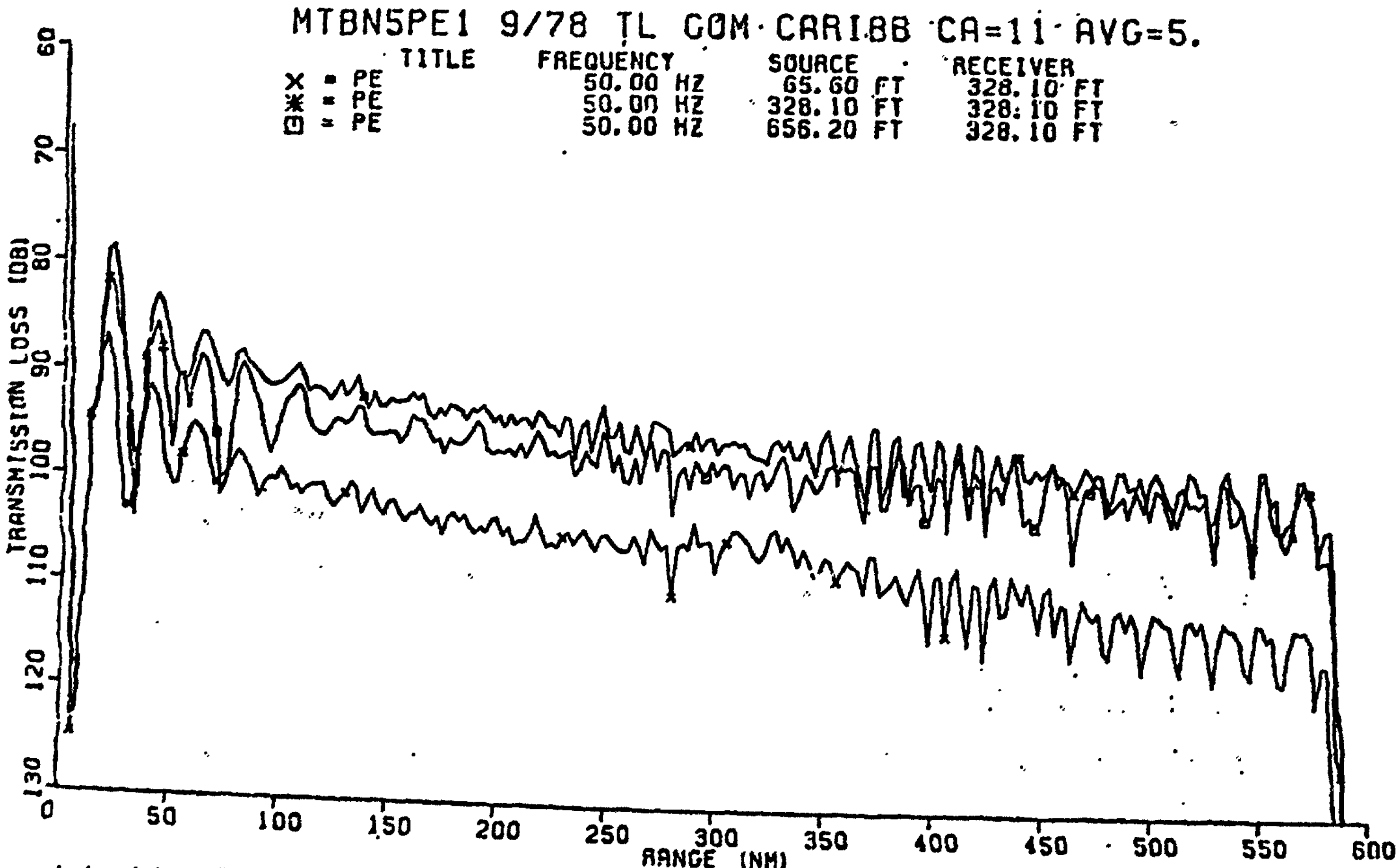

Figure 4-4. (U) PE Propagation Loss Along Track 5. Critical Angle 11°, Receiver Depth 100 m. (U)

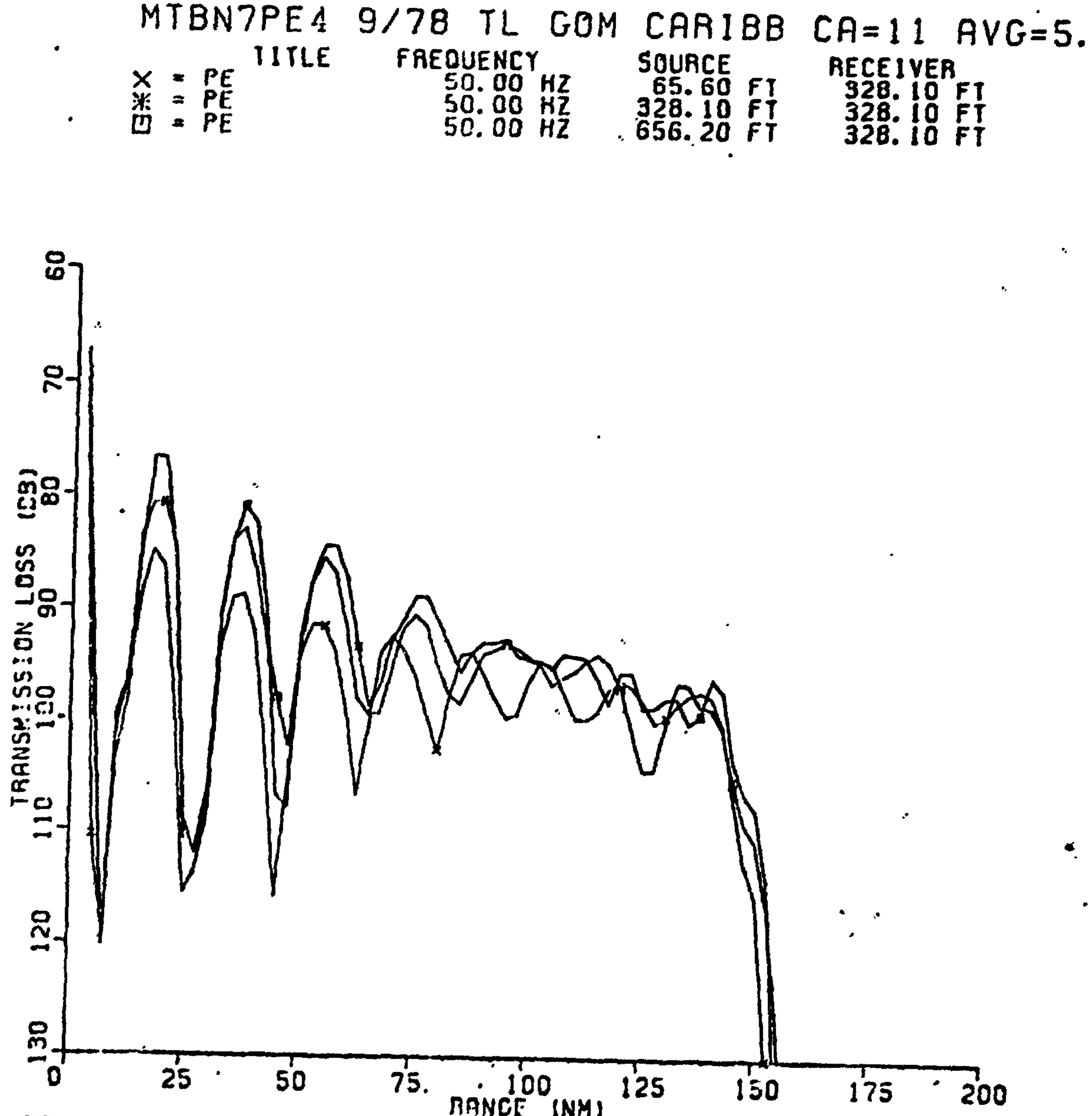

Figure 4-5. (U) PE Propagation Loss Along Track BN 7. Critical Angle 11°, Receiver Depth 100 m. (U)

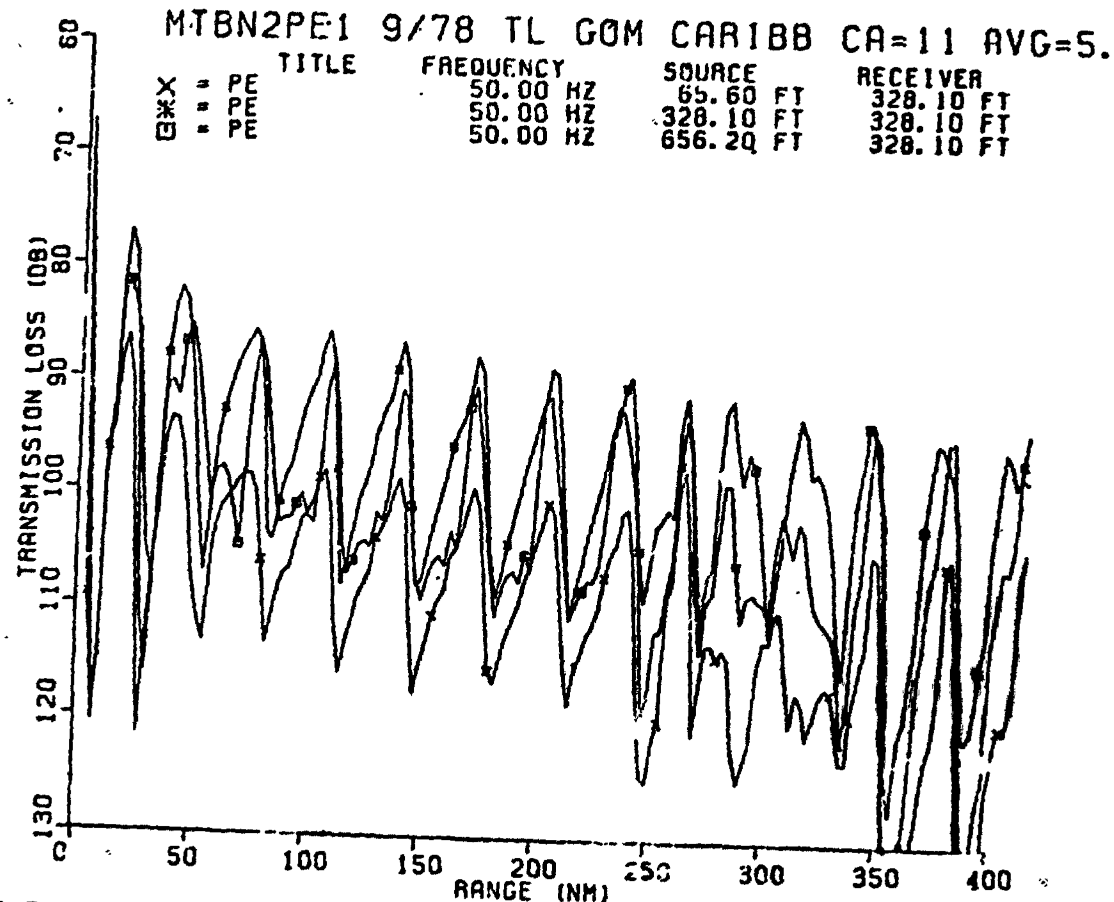

Figure 4-6. (U) PE Propagation Loss Along Track BN 2. Critical Angle 11°, Receiver Depth 100 m. (U)

(U)

one can determine the smallest critical angle required to sustain propagation without bottom loss. This angle is 2.3° for BN5, 7.5° for BN7 and 7.9° for BN2.

(U) A preliminary sensitivity study has been performed along BN3 in order to assess the impact of sources located along slope and shelf regions. See Figure 4-7 for the SYNBAPS bathymetry and sound speed along this track. For a source depth of 300 m and receiver depth of 100 m, the dependence of the 50 Hz transmission loss (5 nm intensity average) on critical angle is shown in Figure 4-8. The critical angle cases correspond to 0° throughout, 5° throughout, 11° throughout and a variable critical angle of 5° on the plain, 19° on the slope and 11° on the shelf. Notice that there is slope conversion of energy for the 11° and variable critical angle cases. These results suggest that for shallow receivers contributions from noise sources on the slope or shelf may be small unless the slope region has a critical angle on the order of 19°. Results from a PE calculation for a deep receiver (800 m) indicate that conversion may be significant even for an 11° critical angle on the slope.

(U) Possible values for the critical angle in the basin, slope and shelf were estimated as follows:

- Cores of the seafloor in the vicinity of Site I and near track BN3 supply information about the physical properties of sediments near the water/bottom interface [20]. These properties together with the physiographic province allow one to enter tables supplied by Hamilton[21] and extract estimates for the bottom water to sediment sound speed ratio. This ratio can be used to calculate a critical angle.

- The results of these calculations were estimates of 5° for the basin province and a range of critical angles from 8° to 24° for the Continental terrace (shelf and slope) province. The spread on the latter estimate is due to

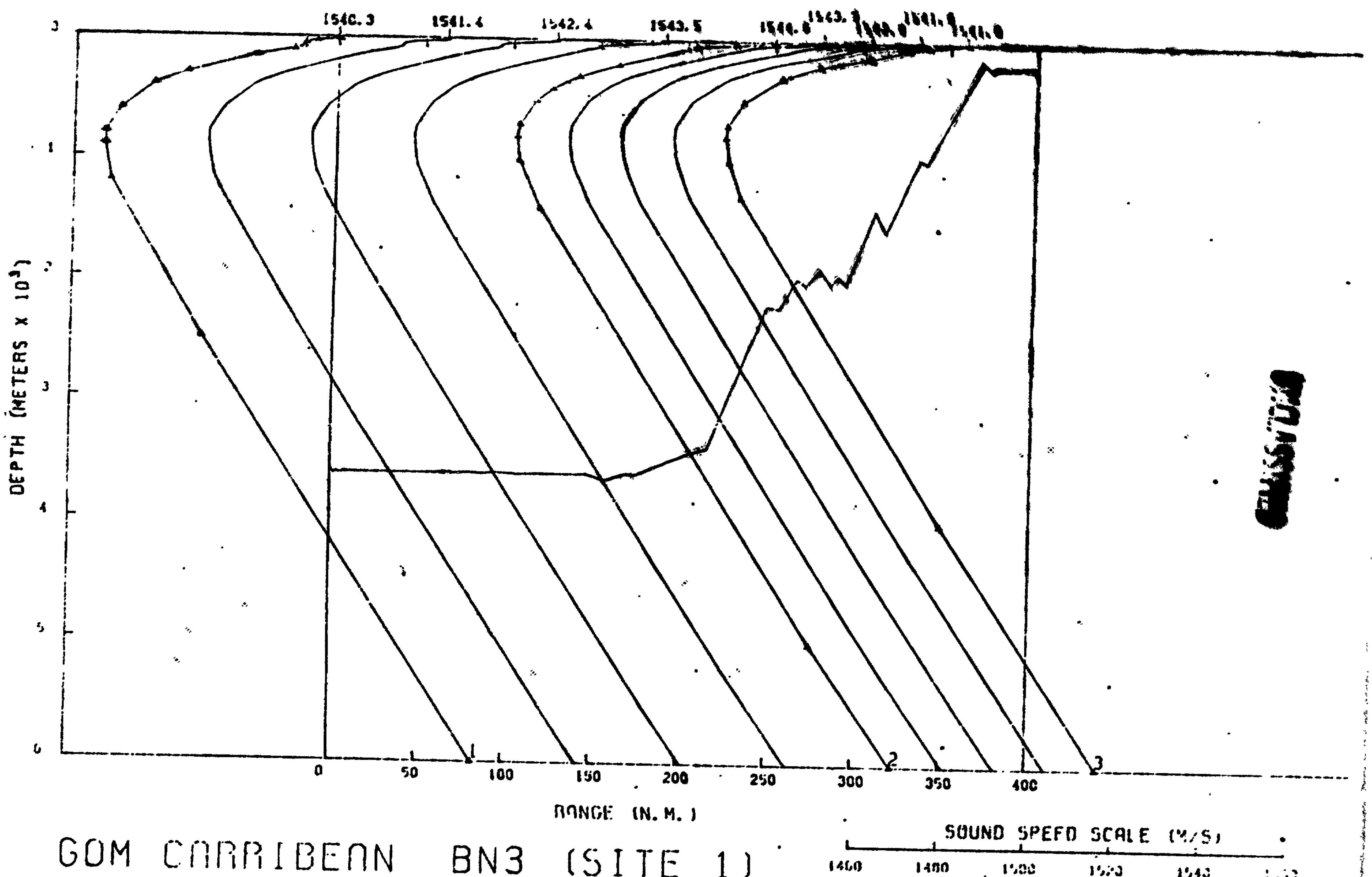

Figure 4-7. (U) Sound Velocity and Bathymetry Profiles for Track BN 3. (U)

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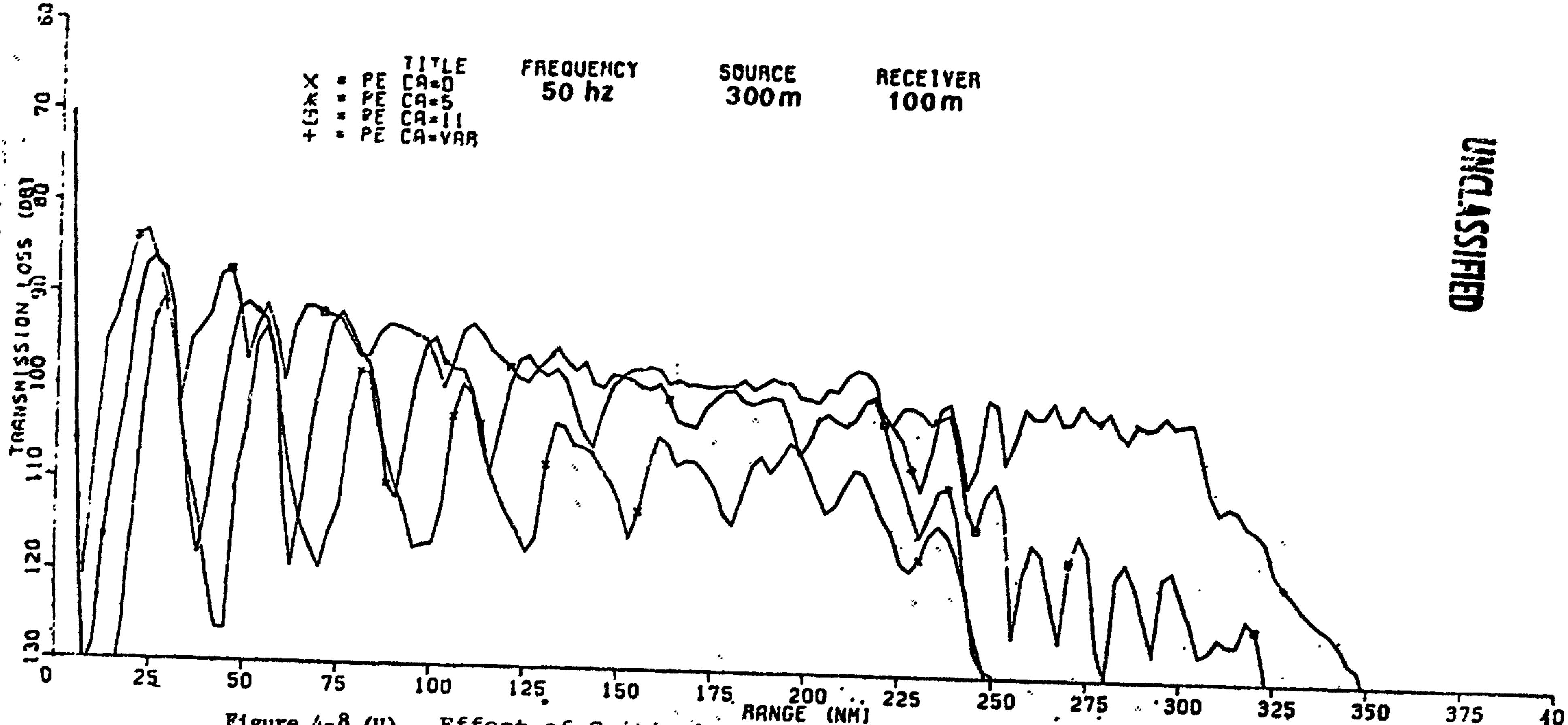

Figure 4-8.(U) Effect of Critical Angle on Propagation Loss Along Track BN 3. (U)

(U)

uncertainty in the proportions of sand, silt and clay in the sediment. An increase in the sand content increases the critical angle due to the marked increase in the sound speed ratio.

- An additional consideration is that critical angles calculated in this way are appropriate for Rayleigh reflection (homogeneous sediment). A strongly refracting (strong gradient of sound speed with depth in the sediment), low absorption sediment will give a higher apparent critical angle by returning energy to the water column by refraction.

(U) In Figures 4-9, 4-10 and 4-11 the dependence of slope conversion on receiver depth is illustrated for the variable critical angle case. The source depths shown are 20, 100, 200 and 300 meters and receiver depths are 100 m in Figure 4-9, 300 m in Figure 4-10 and 860 m in Figure 4-11. The primary conclusion to be drawn from these results is that the deeper the receiver, at least up to axial depth (approximately 860 m), the greater the opportunity for interfering noise sources on the slope and shelf to become significant. Alternatively, a shallow receiver minimizes their effect. This is brought out most vividly in a PE contour map corresponding to a source located up on the shelf which shows energy from the source being converted by the slope into a moderately high intensity band centered about the axial depth. This is illustrated in Figure 4-12 for a reverse track with a source located up on the shelf at a depth of 100 m and receivers moving back along the track at depths of 20, 100, 200, 300, 800 and 1000 m. Figure 4-13 shows the propagation loss in 10 dB intervals for the same conditions. The downslope conversion and channeled propagation are clearly illustrated.

(U) A simplified bathymetry was constructed from the BN3 detailed bathymetry and the slope was represented by a straight line rising approximately 3250 m over a distance of 155 nm. PE model results indicate

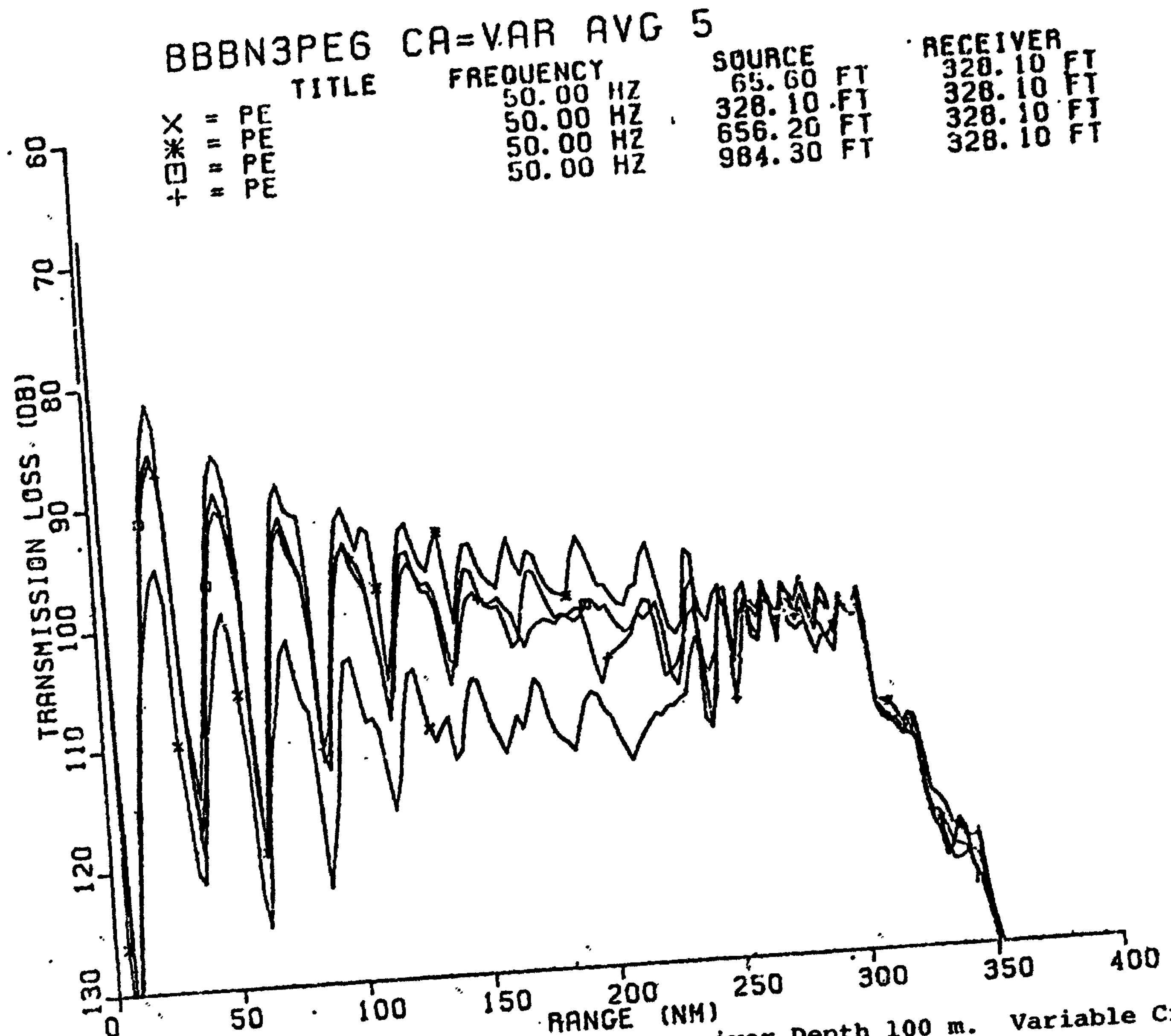

Figure 4-9. (U) PE Propagation Loss Along Track BN 3, Receiver Depth 100 m. Variable Critical Angle Case. See text. (U)

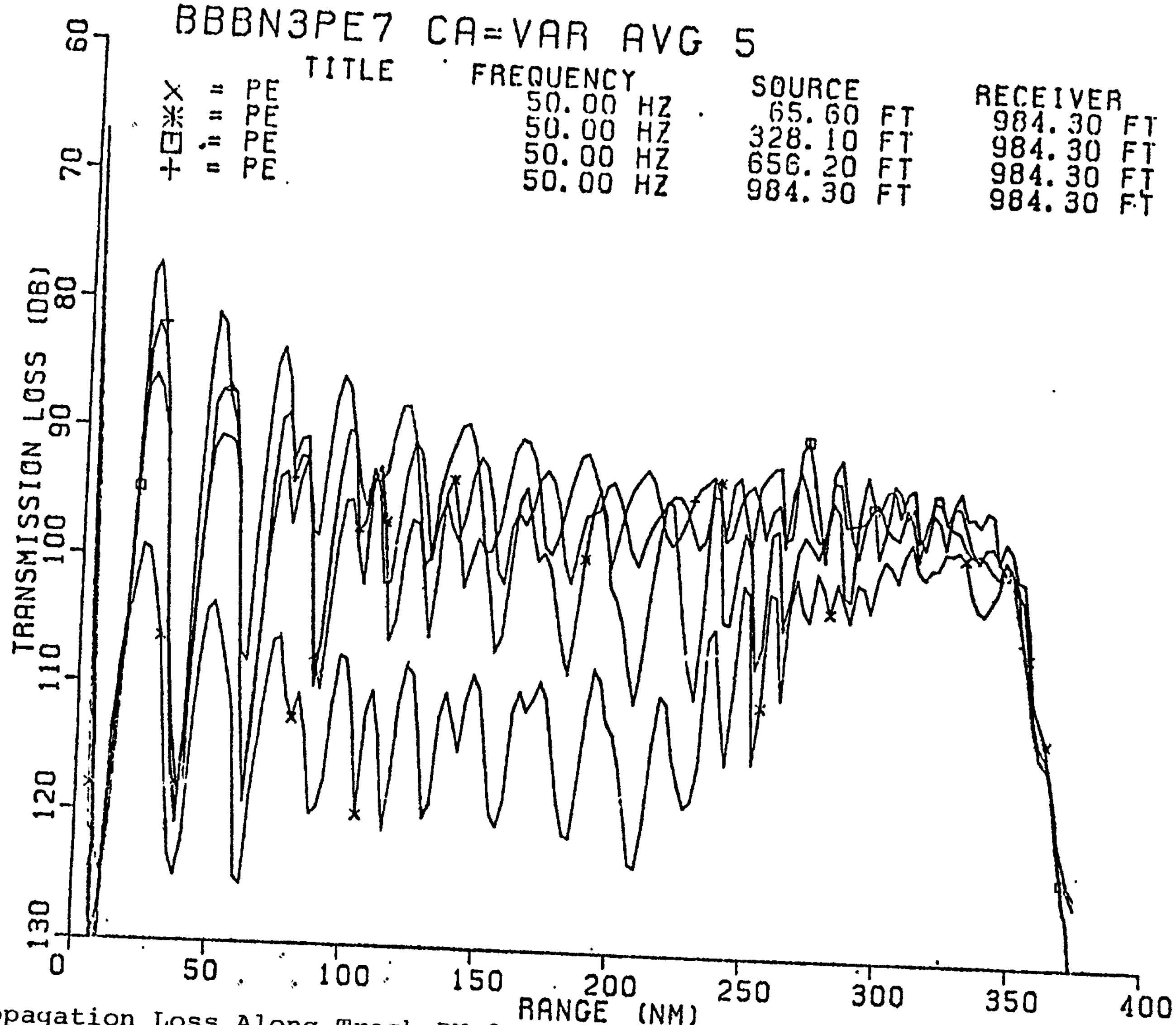

Figure 4-10. (U) PE Propagation Loss Along Track BN 3, Receiver Depth 300 m. Variable Critical Angle Case. See Text. (U)

UNCLASSIFIED

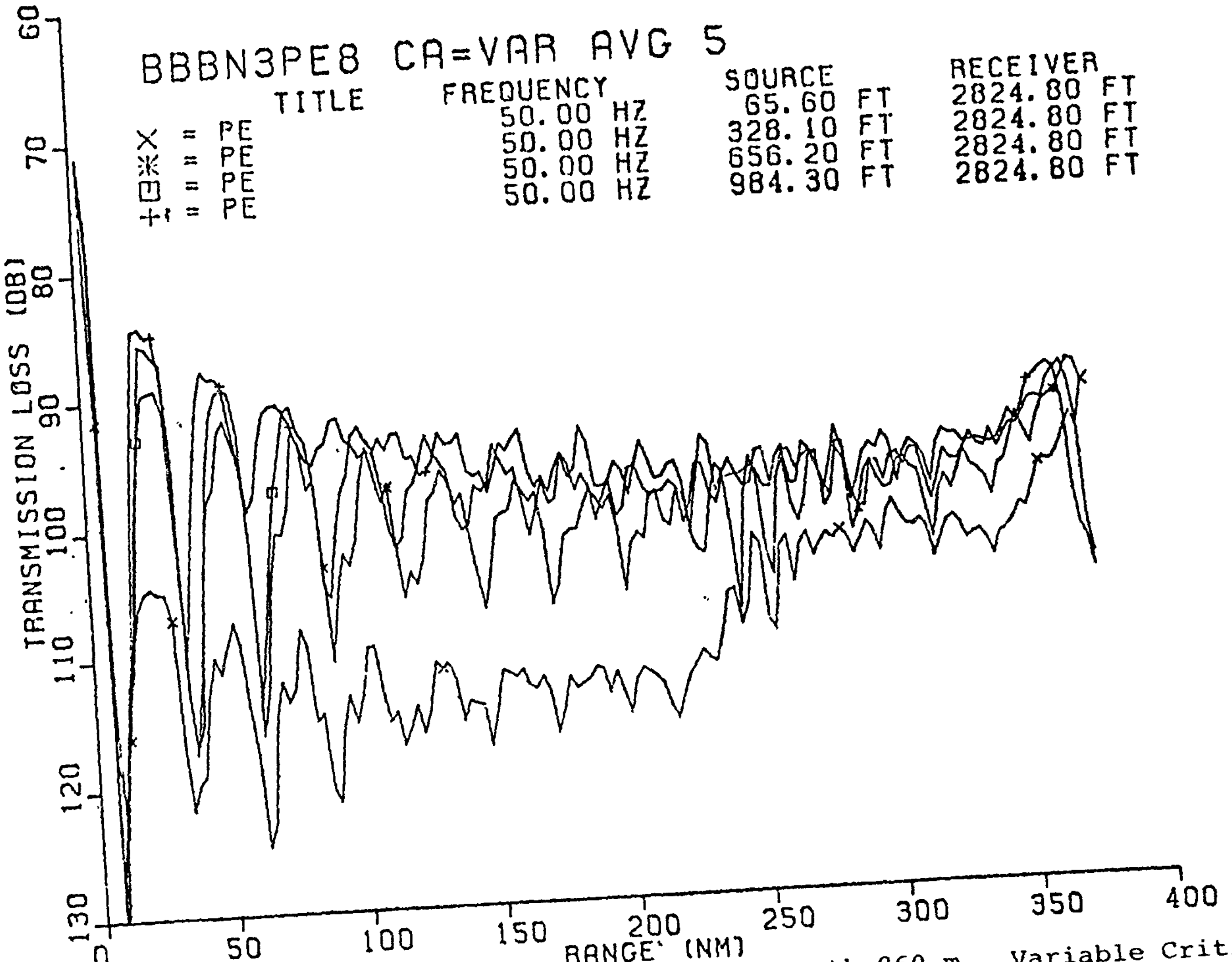

Figure 4-11. (U) PE Propagation Loss Along Track BN 3, Receiver Depth 860 m. Variable Critical Angle Case. See Text. (U)

UNCLASSIFIED

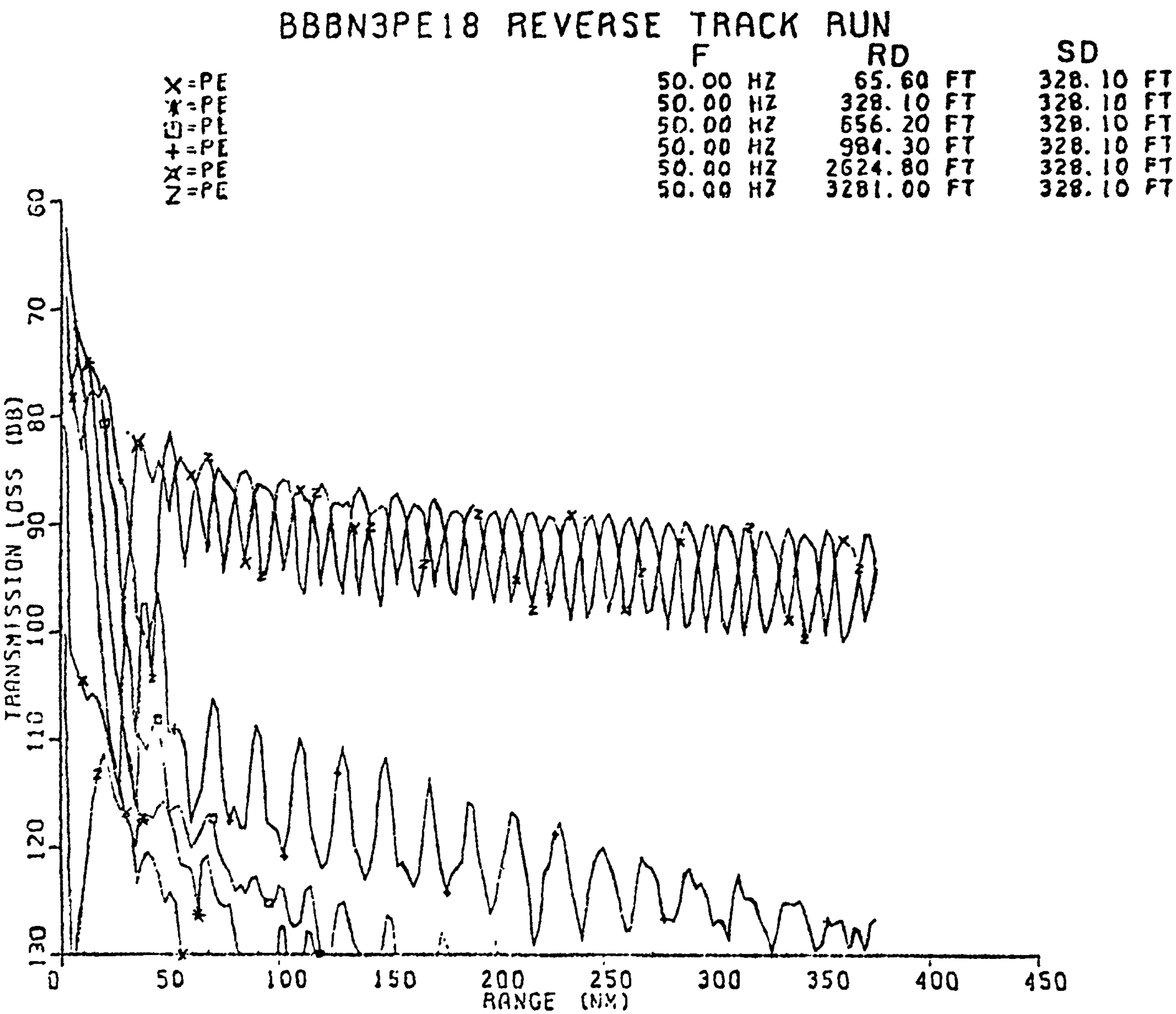

Figure 4-12. (U) PE Propagation Loss Along Reversed Track BN 3, Source Depth 100 m. Variable Critical Angle Case. See Text. (U)

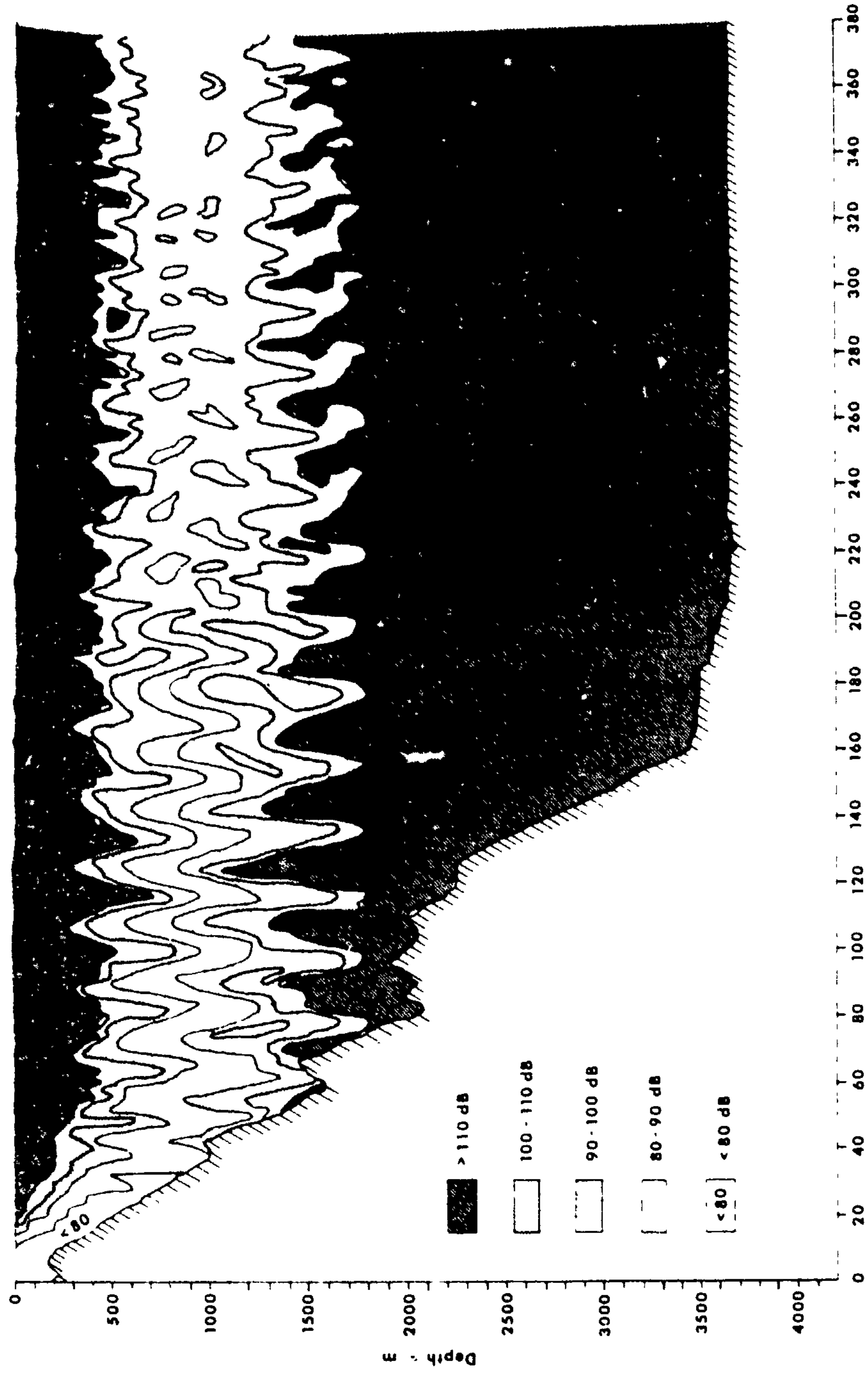

Figure 4-13. (U) PE Propagation Loss Regions for Same Conditions as Figure 4-12. (U)

(U)

essentially the same degree of conversion for this case as for the detailed case. Having this confirmation of equivalence of the simple and detailed slope bathymetry, cases were also constructed for the 3250 m rise occurring over 110 nm and 55 nm range intervals in order to examine dependence of slope conversion effects on steepness of the slope. PE results indicate little difference in the slope conversion (other than a displacement in range). These cases sample most of the slope angles in the area and suggest that slope conversion can be significant throughout the area if the slope reflectivity is high.

(U) ASTRAL runs have also been made along BN3 at 50 Hz to assess its capability to model slope conversion. FNWC bottom types of 4, 1 and 3 were employed respectively on the basin floor, slope and shelf corresponding to the PE variable critical angle case. The sound speed profiles and bathymetry employed were the same ones used in the PE calculation. The unsmoothed ASTRAL results are shown in Figure 4-14 for a receiver depth of 800 m and source depths of 20, 100 and 200 m and indicate that ASTRAL can indeed model slope conversion. Notice the abrupt fall-off at approximately 375 nm over the shelf. An ASTRAL run employing a 19^{o} critical angle for the shelf indicates that the high levels obtained just prior to the drop-off for an 11^{o} critical angle on the shelf will be sustained far onto the shelf. Preliminary results indicate that ASTRAL shows conversion effects even for bathymetry as coarse as 1^{o} (the AUTO-OCEAN bathymetry resolution). This is significant for noise estimates because it suggests that ASTRAL transmission loss based on 1^{o} resolution bathymetry may be adequate along directions off the main beam.

4.1.3 (U) Comparison of Models and Data (U)

(U) No attempt has been made to predict propagation loss along tracks for which there is existing experimental data. The experimental data comparison shown in Figure 3-8 tends to support the general

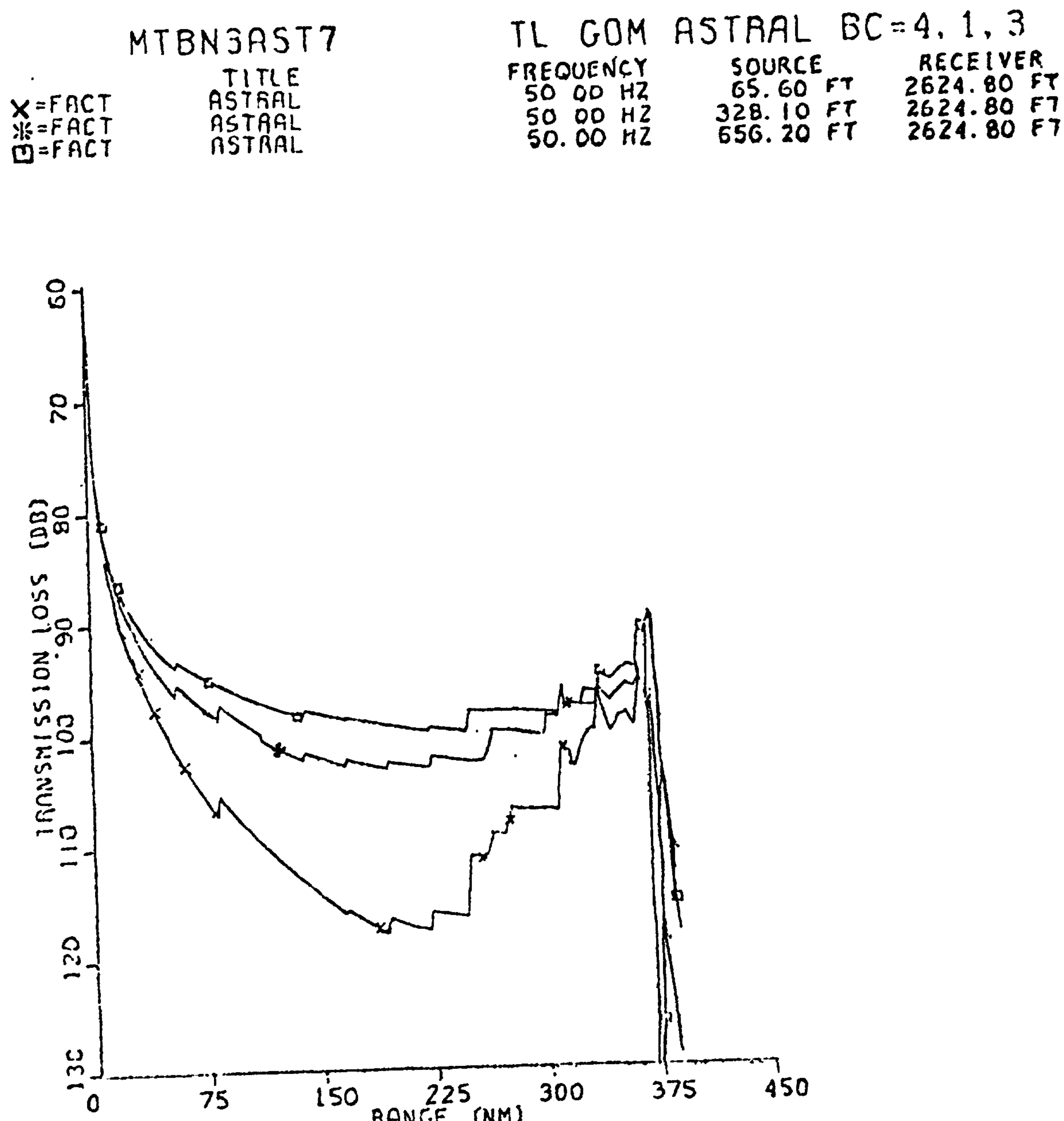

Figure 4-14. (U) ASTRAL Propagation Loss Along Track BN 3. (U)

U)

conclusion that slope conversion and channeling of energy into the deep channel can occur.

4.1.4 (U) Critique (U)

(U) The model computations contained herein are primarily based on the FNWC bottom loss classes available prior to undertaking this pre-assessment. To accommodate the capabilities of the PE model it was necessary to interpret these bottom loss classes in terms of a critical angle. As has been shown in Section 2.6, high critical angles with low bottom loss up to the critical angle are generally the case in the Gulf of Mexico, further tending to indicate that downslope conversion of energy from oil industry sources is likely to occur.

(U) Additional model runs corresponding to specific experimental tracks and measurement system locations will be undertaken to correspond to experiment plans. Model runs with respect to oil industry operation will be undertaken to exemplify the phenomena to be expected, and, if possible, to examine the likelihood of interference from seismic profilers. These model runs will be based on the bottom loss data presented in Section 2.6 and any further improvement in bottom loss estimates which might be made as the pre-assessment proceeds.

4.2 <u>(U) Ambient Noise (U)</u>

4.2.1 (U) Ambient Noise Models (U)

(U) The prediction of ambient noise in the Gulf of Mexico-Caribbean Sea areas is a difficult problem for omnidirectional noise and may not be presently practical for directional noise. Two problem areas are easily identified: (1) the capability to predict transmission loss in a 3-D environment, an environment that is mostly bottom limited and whose bottom properties are poorly known; and (2) a description of the location and properties of the likely noise sources. Given a transmission loss and

(U)

description of the noise sources, there are various models available to predict average omni- and directional noise and noise statistics; FANM[22,23], NABTAM[24], RANDI[25], BEAMPL[26], SIAM[27,28], DSBN[29], USI Array Noise Model[30,31]. Models implementable at NORDA at the present time are FANM, BEAMPL, SIAM and NABTAM. It is unlikely that an automated input algorithm for the USI Array Noise Model will be ready in time to impact the preassessment. At present, two models capable of generating estimates of vertical noise distribution are implemented at NORDA: FANM and NABTAM.

(U) As has been indicated in Section 4.1.1, the ability to predict transmission loss is presently limited to 2-D models. The departure of a composite set of 2-D transmission loss estimates from the true 3-D field may be sufficient to reduce reliability of directional noise calculations in this ocean region. However, for preassessment purposes we are limited to use of 2-D models. In addition, the 2-D transmission loss predictions must be based on estimates of bottom interaction parameters, and noise estimates are expected to be extremely sensitive to bottom properties. A major difficulty in noise prediction is in estimating the contribution of oil rigs and seismic exploration. The impact of these sources is strongly dependent upon bottom properties on the shelf and slope and on characteristics of the sources (source level, location) which may not be well known.

(U) These modeling and data base deficiencies serve to underline the importance of collecting good noise, transmission loss and environmental data in order to identify the relative importance of deficiencies in the various components required for reliable noise predictions.

(U) Prior to addressing in a positive sense what can be done in the way of noise modeling, in view of the aforementioned limitations, and prior to discussing the various noise models and making a recommendation for pre-assessment purposes, it is necessary to outline some additional

(U)

noise modeling considerations. These will set the recommendation within the proper framework, i.e., the ability to distinguish between the various components required for the prediction which represent a certain stage of the art, and the compromises required because the separate components do not exist as a whole and cannot be drawn together in time for preassessment purposes. This also serves to highlight priorities for future model-data base-development.

- SURFACE SHIPPING. The most up-to-date shipping information is the PSI worldwide, monthly, 1° descriptions for fishing vessels, merchant ships, tankers and large tankers[32]. It is clearly desirable to use this data base despite uncertainties in source level, but it is not certain whether it can be implemented for use in noise models in time for preassessment. It can, however, be hand-processed for certain "look" directions as input for example to BEAMPL or perhaps DSBN. We may have to rely on shipping information already accessible in AUTO-SHIPS for the NORDA models or alternatively those in the data base for RANDI.

- OIL RIGS. Locations of oil rigs are contained in the PSI worldwide shipping descriptions, but it is doubttul that this information can be utilized by any existing noise model except by (1) preprocessing which takes into account at a given frequency the azimuthal transmission loss, the location and source level of the rigs, and (2) is manually inserted as a directionally-dependent background noise in the model.

- TRANSMISSION LOSS. The possible significance of noise contributors located over slope or shelf regions strongly suggests that transmission loss for noise prediction purposes must be available along many radials from a given site in order to describe the azimuthal noise dependence. This in

(U)

turn implies that (1) it may be extremely expensive in computer and set-up time, (2) some automation is required relative to the sound speed, bathymetry and bottom type information input, (3) the sound speed resolution must account for the regional area variations that are acoustically significant, (4) the bathymetry resolution must be adequate and (5) a detailed bottom description must be available.

- SOUND SPEED. Automatic data bases for sound speed include 5° resolution AUTO-OCEAN and/or 5° resolution available in the ASEPS (NOSC) data base[33]. Finer resolution requires processing through retrieval programs such as RSVP.

- BATHYMETRY. Bathymetry is available from AUTO-OCEAN with a 1° resolution that is an automatic model input but may be too crude, $1/6^{\circ}$ resolution in ASEPS (NOSC), and $1/12^{\circ}$ from SYNBAPS (not available as automatic model input).

- BOTTOM LOSS. FNWC bottom loss descriptions are available through AUTO-OCEAN and through ASEPS. These descriptions are uniformly Type 4 in AUTO-OCEAN for the exercise area and felt (by NORDA) to be a poor description of the area. A better description of the area is required. Estimates presented in Section 4.1.2 indicate that the bottom may be a much better reflector than FNWC Type 4.

(U) The following recommendations re noise modeling for preassessment are ordered according to decreasing implementation probability and are subject to revision by the results of ongoing investigations:

- Use BEAMPL (or DSBN if implementable) for selected primary look directions. This has the advantage that it can utilize a high confidence transmission loss estimate (PE or UNIMOD,

(U)

if ready) based on carefully developed environment (SVP, bathymetry, bottom properties) and the new PSI shipping. Include oil rig contributions as a background level in the bea n.

- Use SIAM with the new PSI shipping (if ready in time), PE (or UNIMOD) along main look directions, and ASTRAL off the main lobe. A potential difficulty here is automatic access to SYNBAPS or ASEPS bathymetry for the ASTRAL model.

- Same as above except that ASTRAL TL be obtained from ASEPS (NOSC).

4.2.2 (U) Ambient Noise Model Runs (U)

(U) No ambient noise model runs have been made.

4.2.3 (U) Comparison of Models and Data (U)

(U) Since no model runs have been made, no comparison with data can be made.

4.2.4 (U) Critique (U)

(U) Because of the complexity of the area the performance of model ambient noise runs is a difficult problem. This matter will be given additional consideration as the pre-assessment proceeds. The order of emphasis will be to first attempt a description of the general features of the noise field that might be expected, and second to compute quantitative noise levels. Quantitative computations are likely to be based on a fractionation of the noise sources with separate considerations of nearby ships, ships in the major basins, ships over the sloping areas, and oil industry sources on the slopes and shelves.

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5.0 (C) PRE-EXERCISE MODEL RUNS REQUESTED (U)

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With The Assistance of The Principal Investigators
and Exercise Planners

(C) Tables 5-1 through 5-6, developed through consultations among the pre-assessment Technical Director, pre-assessment Principal Investigators, and the designated Exercise Planners, define the pre-exercise model runs that are requested. The pertinent parameters are specified and priorities indicated. The requested runs are categorized as follows:

- Table 5-1 Propagation Loss Runs, Priority 1, Western Gulf.
- Table 5-2 Propagation Loss Runs, Priotity 2, Eastern Gulf
- Table 5-3 Propagation Loss Runs, Priority 3, Cruise 2
- Table 5-4 Ambient Noise Runs, Priority 1, Western Gulf
- Table 5-5 Ambient Noise Runs, Priority 2, Eastern Gulf
- Table 5-6 Ambient Noise Runs, Priority 3, Cruise 3

TABLE 5-1

PROPAGATION LOSS RUNS, PRIORITY 1, WESTERN GULF

Receiver Location			To Track End			Receiver Depth (m)			Source			Models		Priority		
Datum	Lat N	Long W	Datum	Lat N	Long W	Above Bottom	Below Surface	Type	Depth	Type	Frequencies	Prim	Sec	1G	1P	
1A	23-00	91-30	1G	29-10	85-51		400	LAMBDA	18.3	-	25, 67, 147	PE	ASTRAL	1	1	
				and			200	"	91.4	CW	"	"	"	1	1	
			50	nm beyond			300	"	18.3	-	"	"	"	1	1	
			1P	28-00	91-30		800	"	91.4	CW	"	"	"	1	1	
						945		ACOGAC	18.3	SUS	25, 147	"	"	1	1	
						945		"	91.4	"		"	"	1	1	
						945		"	274.3	"		"	"	1	1	
						1800		"	18.3	"		"	"	1	1	
						1800		"	91.4	"		"	"	1	1	
						1800		"	274.3	"		"	"	1	1	
						2900		"	18.3	"		"	"	1	1	
						2900		"	91.4	"		"	"	1	1	
						2900		"	274.3	"		"	"	1	1	
														1D		
1B	24-25	93-03	1D	25-42	94-30	100		FAR	91.4	CW	67, 147, 300, 600	FACT	ASTRAL	1	-	Range-Invariant
						100		"	On Axis	Moored	165	N Mode	FACT	1	-	Note 1
							300	"	91.4	CW	67, 147, 300, 600	FACT	ASTRAL	1	-	Range-Invariant
							300	"	On Axis	Moored	165	N Mode	FACT	1	-	Note 1
																Note 1
														1A		NORDA 320 - 2 FACT runs each
1A	23-00	91-30	-	21-00	97-15		400	LAMBDA	18.3	-	25, 67, 147	PE	-	1	-	using SAI and ARL bottom
							800	LAMBDA	18.3	-	25, 67, 147	PE	-	1	-	loss curves.
																ARL/UT - N. Mode using
																physical bottom parameters
																which led to ARL bottom loss
																curves

TABLE 5-2

PROPAGATION LOSS RUNS, PRIORITY 2, EASTERN GULF

Receiver Location			To Track End			Receiver Depth (m)			Source			Models		Priority		
Datum	Lat N	Long W	Datum	Lat N	Long W	Above Bottom	Below Surface	Type	Depth	Type	Frequencies	Prim	Sec	F	G	
E	23-37	86-00	F	25-22	83-30	945		ACODAC	18.3	SUS	25, 147	PE	ASTRAL	1	1	
				and		945		"	91.4	"	"	"	"	1	3	
			G	22-40	87-19	945		"	274.3	"	"	"	"	4	4	
						1800		"	18.3	"	"	"	"	1	1	
						1800		"	91.4	"	"	"	"	1	3	
						1800		"	274.3	"	"	"	"	4	4	
						2500		"	18.3	"	"	"	"	1	1	
						2500		"	91.4	"	"	"	"	1	3	
						2500		"	274.3	"	"	"	"	1	4	
							200	LAMBDA	18.3	-	67, 147	"	"	1	1	
							200	"	91.4	CW	"	"	"	1	3	
							200	"	274.3	-	"	"	"	1	4	
							800	"	18.3	-	"	"	"	1	1	
							800	"	91.4	CW	"	"	"	1	3	
							800	"	274.3	-	"	"	"	4	4	
														H	I	
E	23-37	86-00	H	22-27	85-02	945		ACODAC	18.3	SUS	25, 147	PE	ASTRAL	1	1	
				and		945		"	91.4	"	"	"	"	1	1	
			I	25-41	87-46	945		"	274.3	"	"	"	"	4	4	
						1800		"	18.3	"	"	"	"	1	1	
						1800		"	91.4	"	"	"	"	1	1	
						1800		"	274.3	"	"	"	"	4	4	
						2500		"	18.3	"	"	"	"	1	1	
						2500		"	91.4	"	"	"	"	1	1	
						2500		"	274.3	"	"	"	"	1	1	
							200	LAMBDA	18.3	-	"	"	"	2	2	
							200	"	91.4	-	"	"	"	2	2	
							200	"	274.3	-	"	"	"	2	2	
							800	"	18.3	-	"	"	"	4	4	
							800	"	91.3	-	"	"	"	4	4	
							800	"	274.3	-	"	"	"	4	4	
														C		
E	23-37	86-00	C	24-40	84-30		200	LAMBDA	On Axis	Moored	165	PE	ASTRAL	1		
							800	LAMBDA	On Axis	Moored	165	PE	ASTRAL	1		

TABLE 5-2 CONT'd

Receiver Location			To Track End			Receiver Depth (m)			Source			Models		Priority		
Datum	Lat N	Long W	Datum	Lat. N	Long W	Above Bottom	Below Surface	Type	Depth	Type	Frequencies	Prim.	Sec.	J	K	
D	24-09	85-14	J	23-07	84-22		200	PAR	18.3	SUS	25, 147	N. Mode	FACT	1	2	
				and			200	"	91.4	"	"	"	"	1	2	
			K	28-15	88-46	1600		"	18.3	"	"	"	"	1	2	
						1600		"	91.4	"	"	"	"	1	2	
						60		"	91.4	S. Aug	71, 302	"	"	1	-	
														N		
D	24-09	85-14	N	26-07	87-00	60		PAR	61.0	S. Aug	71, 302	N. Mode	FACT	2	-	
						60		PAR	91.4	S. Aug	71, 302	N. Mode	FACT	2	-	
														CUBA		
A	24-14	81-48	- To	Cuba	-	On Bottom-(548.6)		VEKA	91.4	CW	67, 147	PE	ASTRAL	3	-	
			thru	Datum B												

TABLE 5-3

PROPAGATION LOSS RUNS, PRIORITY 3, CRUISE 2

[illegible] Location			[illegible] Track [illegible]			Receiver Depth (m)			Source			Models		Priority		
Station	Lat °N	Long °W	Datum	Lat °N	Long °W	Above Bottom	Below Surface	Type	Depth	Type	Frequencies	Prim.	Sec			
H	20-30	84-45	D	17-25	86-40	30		PAR	18.3	SUS	25, 147	ASTRAL	PE	3	-	Make a few PE runs to
						30		"	91.4	SUS	25, 147	"	"	3	-	compare with ASTRAL
						30		"	91.4	CW	67, 147	"	"	1	-	
						310		"	18.3	SUS	25, 147	"	"	3	-	
						310		"	91.4	SUS	25, 147	"	"	3	-	
						310		"	91.4	CW	67, 147	"	"	2	-	
						1000		"	18.3	SUS	25, 147	"	"	3	-	
						1000		"	91.4	SUS	25, 147	"	"	3	-	
						1000		"	91.4	CW	67, 147	"	"	1	-	
							200	-	91.4	-	25, 147	"	"	2	-	
H	20-30	84-45	F	22-50	87-10	30		PAR	18.3	SUS	25, 147	ASTRAL	PE	2	-	Same note as above
						30		"	91.4	SUS	25, 147	"	"	3	-	
						30		"	91.4	CW	67, 147	"	"	3	-	
						1000		"	18.3	SUS	25, 147	"	"	2	-	
						1000		"	91.4	SUS	25, 147	"	"	3	-	
						1000		"	91.4	CW	67, 147	"	"	3	-	
							200	-	91.4	-	25, 147	"	"	3	-	
G	20-40	84-35	J	16-22	83-20	30		PAR	91.4	CW	67, 147, 302	PE	ASTRAL	1	-	ASTRAL runs only if
						600		PAR	91.4	CW	67, 147, 302	PE	ASTRAL	1	-	desired for comparison
						1470		PAR	91.4	CW	67, 147, 302	PE	ASTRAL	1	-	

TABLE 5-3 CONT'd

Receiver Location			To Tra[illegible]			[illegible] (m)			[illegible]		[illegible]	Mode				NOTE
Datum	Lat N	Long W	Datum	Lat N	Long W	Above Bottom m	Below Surface	Type	[illegible]	Type	[illegible]	From	To			
D	17-25	86-40	H	20-30	84-45	30		ACODAC	18.3	[illegible]	25, 147	[illegible] Mode	FACT	3	-	
						30		"	91.4	505	25, 147	Mode	FACT	1	-	
						30		"	91.4	CW	67, 147	ASTRAL	FF	2	2	
						945		"	18.2	505	25, 147	Mode	FACT	3	-	
						945		"	91.4	[illegible]	25, 147	Mode	FACT	1	-	
						945		"	91.4	CW	67, 147	ASTRAL	FF	2	2	
						1800		"	18.3	[illegible]	25, 147	Mode	FACT	3	-	
						1800		"	91.4	505	25, 147	Mode	FACT	[illegible]	-	
						1800		"	91.4	CW	67, 147	ASTRAL	FF	[illegible]	2	
							200	LAMBDA	91.4	CW	67, 147	FF	ASTRAL	1	3	
							800	LAMBDA	91.4	CW	67, 147	FF	ASTRAL	1	3	
D	17-25	86-40	A	19-30 and	74-20	30		ACODAC	18.2	505	25, 147	FF	ASTRAL	[illegible]	3	
						30		"	91.4	"	"	"	"	1	3	
			C	18-10	83-20	945		"	18.2	"	"	"	"	3	3	
						945		"	91.4	"	"	"	"	1	2	

NOTE

SYNBAPS outputs to be provided [illegible]

From	To
F	GH
H	D
GH	C
A	B
B	[illegible]
C	D
A	[illegible]
A	[illegible]

TABLE 5-4

AMBIENT NOISE RUN, PRIORITY 1, WESTERN GULF

Receiver Location			Receiver Depth (m)			[illegible] Type	Frequency	Model		Priority		
Datum	Lat N	Long W	Above Bottom	Below Surface	Type			Prim	Sec			
1A	23-00	91-10		200	LAMBDA	Omni	25, 67, 147	STIAM	FANM	1	1	STIAM/FANM comparisons
				200	"	Hor. Dir.	"	STIAM	BEAMPL	1	1	STIAM - Av. value, 10° sector, BEAMPL - Note 1
				800	"	Omni	"	STIAM	FANM	1	1	STIAM/FANM comparisons
				800	"	Hor. Dir.	"	STIAM	BEAMPL	1	1	STIAM-Av. value, 10° sector, BEAMPL - Note 1
1B	24-25	91-03	100		PAR/RDSS	See Notes	67, 147, 300, 600			1		Provide omni av. value and hor. and vert.
			300		PAR/RDSS	See Notes	67, 147, 300, 600			1		dir. structure - Note 2
1D	25-45	94-10		200	LAMBDA	Omni	25, 67, 147	STIAM	FANM	2	2	Same notes as for Datum 1A
				200	"	Hor. Dir	"	STIAM	BEAMPL	2	2	" "
				800	"	Omni	"	STIAM	FANM	2	2	" "
				800	"	Hor. Dir	"	STIAM	BEAMPL	2	2	" "
			10		PAR ACODAC	Omni.	67, 147, 300, 600	STIAM	FANM	2	3	NOTE 1
			600		PAR ACODAC	Omni	67, 147, 300, 600	STIAM	FANM	2	3	BEAMPL - 10°, in direction of 1A and 1D only
			1800		PAR/ACODAC	Omni	67, 147, 300, 600	STIAM	FANM	2	3	Cumulative noise distribution will be provided
				300	PAR/ACODAC	Omni.	67, 147, 300, 600	STIAM	FANM	2	4	

All noise will be computed separately for
- Fishing vessels and wind
- Merchant ships
- Oil platforms and rigs
- Total

NOTE 2

Contingent upon NORDA 320 capability

TABLE 5-5

AMBIENT NOISE RUNS, PRIORITY 2, EASTERN GULF

Receiver Station			Receiver Depth (m)			Computational		Models		Priority		
Station	Lat N	Long W	Above Bottom	Below Surface	Type	Type	Frequencies	Prim.	Sec.			
L	23-37	86-00		200	LAMBDA	Omni.	25, 67, 147	∫SIAM	FANM	1	1	SIAM/FANM comparisons
				200	"	Hor. Dir.	"	SIAM	BEAMPL	1	1	SIAM - Av. value, 10° sector. BEAMPL - Note 1
				800	"	Omni.	"	∫SIAM	FANM	1	1	SIAM/FANM comparisons
				800	"	Hor. Dir.	"	SIAM	BEAMPL	1	3	SIAM - Av. value, 10° sector. BEAMPL - Note 1
			30		ACODAC	Omni.	"	∫SIAM	FANM	1	1	Select between ∫SIAM & FANM based on above
			200		"	"	"	"	"	1	1	" comparisons, technical judgement, and
			640		"	"	"	"	"	1	1	" cost considerations.
			945		"	"	"	"	"	1	1	"
			1800		"	"	"	"	"	1	1	"
			2200		"	"	"	"	"	1	1	"
D	24-09	85-14		200	-	Omni.	25, 67, 147	∫SIAM	FANM	1	1	Choose between models
			60		PAR	Omni.	25, 67, 147	∫SIAM	FANM	1	1	Choose between models
			60		PAR	Hor. Dir.	25, 67, 147	SIAM	-	2	1	One value for each of NE, SE, SW, & NW sectors
A	24 14	81-48	On Bottom		VEKA	See Notes	25, 67, 147	ASEPS	-	4	-	Standard omni. & directional predictions

NOTE 1

BEAMPL - 10°, in direction of F, G, H, I, L only after examination of SIAM in those directions. Gottwald to select after consultation with Davis.

TABLE 5-6

AMBIENT NOISE RUNS, PRIORITY 3, CRUISE 2

Receiver Location			Receiver Depth (m)			Computational Type	Frequencies	Models		Priority		
Datum	Lat N	Long W	Above Bottom	Below Surface	Type			Prim	Sec			
D	17-25	86-40	30		PAR	Omni.	25, 67, 147, 300,600	∫SIAM	ASEPS/PAHM	1	1	SIAM/ASEPS/PAHM comparisons. Select model.
			200		"	"	"	"	"	1	1	" "
			945		"	"	"	"	"	1	1	" "
			1800		"	"	"	"	"	1	1	" "
H	20-30	84-45	30		PAR	Omni.	25, 67, 147, 300,600	∫SIAM	ASEPS/PAHM	1	1	(same as above)
			310		PAR	Omni.	25, 67, 147, 300,600	∫SIAM	"	1	1	
			1000		PAR	Omni.	25, 67, 147, 300,600	∫SIAM	"	1	1	"
M	18-28	81-44		200	LAMBDA	Omni.	25, 67, 147	∫SIAM	PAHM	1	1	
	and			200	"	Hor. Dir	"	SIAM	BEAMPL	1	2	SIAM - Av. value, 10° sector. BEAMPL Hi & Lo Dir.
E	17-19	87-10		800	"	Omni.	"	∫SIAM	PAHM	1	1	
				800	"	Hor. Dir.	"	SIAM	BEAMPL	1	2	" " " "

6.0 (U) CONCLUSIONS (U)

M. S. Weinstein
Underwater Systems, Inc.

(U) The Western Gulf of Mexico, eastern Gulf of Mexico, Straits of Florida, Yucatan Channel, Yucatan Basin and Cayman Trough provide a rather large diversity of environmental conditions. All regions of the Gulf and the Yucatan Channel are bottom-limited. The Yucatan Basin includes areas with limited depth excess, and the Cayman Trough provides good depth excess. There is an extensive oil industry in the Gulf of Mexico that is expected to contribute to the ambient noise in the western portion; in the Straits of Florida local shipping is expected to dominate; in the eastern Gulf both local shipping and oil industry noise may be important; in the Cayman Trough local and long range shipping located over the Trough are expected to be important; and there may be some coupling of noise between the Gulf and the Yucatan Basin via the Yucatan Channel. Each of these areas has been examined through the use of existing data and model runs to highlight the important acoustic and environmental factors. The specific conclusions presented below are based on this data and inferences that can be drawn from it.

(U) The most important specific conclusion reached is that:

- Noise generated by oil industry operations is likely to have a major impact in the western part of the Gulf of Mexico, but no experimental noise data to either confirm or deny this expectation exist.

(U) Considering each of the subjects discussed in the report, other conclusions reached are:

- Bathymetric data are adequate.
- Archival data on weather and climatology, ocean fronts and currents, sound speed structure, and depth excess are adequate to describe the features of the area in sufficient detail for experimental planning.

(U)

- Ocean currents are high and variable in the Straits of Florida and should be taken into consideration in planning vertical line array installations.
- Bottom loss estimates appear to be adequate in a broad sense. However, they may not be sufficiently accurate for predicting propagation from the regions of dense oil production platforms in shallow water to sensors in deeper water. Similarly, since the area is bottom-limited, they may not be sufficiently accurate to predict propagation loss along any particular track.
- Archival data on the density and location of oil production platforms, oil drill rigs, and seismic profilers are excellent for United States waters in the Gulf of Mexico, and limited for Mexican waters.
- Signals generated by seismic profilers are expected to be a major source of interference in the western Gulf, and will also be important in the eastern Gulf, with the latter conclusion confirmed by existing experimental data. This is due to the high source levels.
- Signals generated by individual drill rigs, particularly those in the deeper shelf or slope region, may propagate effectively by downslope conversion into deep channel modes. Rigs that produce particularly strong signals could be used as beacons for array orientation and signal gain measurements.
- Signals generated by the large number of oil production rigs in the shallow regions need to propagate through extensive shallow water before they can influence the noise levels in the deeper regions. Their impact then depends upon the bottom properties in the shallow water regions.

(U)

- Model studies indicate that the effect of oil industry operation may be a strong dependence of noise levels on depth in the western and eastern Gulf, with the levels peaking about the deep sound channel axis due to downslope conversion. If this occurs, the effect should be minimal for shallow or deep sensors, well removed from the sound channel axis.
- There are no ambient noise data in the western Gulf.
- Omnidirectional noise data as a function of depth are available in the remaining areas. Data in the eastern Gulf do not indicate a peaking of noise levels at the deep sound channel, although there is evidence of seismic profiler interference. However, the data were obtained under conditions least likely to show the anticipated effects of oil industry operations, and are therefore judged to be inconclusive.
- There are no horizontal directionality noise data in any of the areas of interest.
- There are adequate vertical directionality noise data in the Cayman Trough.
- Propagation loss data in the Gulf of Mexico are of limited utility. What is available indicates that channeled propagation between a deep source and receiver is very good, as one might expect. One data set supports the results of modeling efforts suggesting downslope conversion of energy for a source in 600 ft of water.
- Propagation loss data obtained in CHURCH GABBRO for the Cayman Trough are adequate.
- Archival shipping data are adequate, but the algorithms used to distribute the ships in this area require refinement.

(U)

- There is considerable ship traffic over the slopes so that downslope conversion may affect ship noise as well as oil industry noise.
- Frequencies selected for towed sources should avoid the dominant oil drilling rig line frequencies of 12 Hz and 15 Hz and their harmonics.
- Models for predicting propagation loss in relatively flat bottom-limited areas are adequate, but the accuracy of the predictions is a function of the accuracy to which the bottom properties are known.
- Propagation loss prediction in the Cayman Trough requires a three-dimensional model if reflections from the sides of the Trough are to be taken into account.
- The easiest area for propagation loss prediction is likely to be the Yucatan Basin.
- The prediction of ambient noise is a particularly difficult problem because of the location of the noise sources on the slopes in the Gulf of Mexico. As in the case of propagation loss, the accuracy of the noise predictions depends on the adequacy of the bottom loss data.
- Because of the above noted difficulties in modeling, it is likely that the predictions will be more valuable for understanding the phenomena to be expected than for specific numerical values. Comparisons of predictions performed prior to the experiment with data obtained during the experiment represent a very strong test of modeling capabilities.

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